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QOS Enhancement for OFDM System Using Queuing Theory and an Optimized Estimator

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Abstract-**To the problem of bit and power allocation in Orthogonal Frequency Division Multiplexing (OFDM) system, a novel framework was proposed which introduced the Game theory and a new algorithm was applied. Firstly, the power allocation problem was described as non-cooperative Game process. Secondly, combined with influences of required quality of service (QoS). In this paper, we propose a novel SNR estimation algorithm with game theory for wireless OFDM systems based on the reuse of the synchronization preamble and efficient channel allocation based on its service and arrival rates. The periodic structure of the preamble is utilized for the computationally efficient SNR estimation algorithm, based on the second-order moments of received preamble samples. The performance of the proposed algorithm is compared with the MMSE algorithm and two preamble-based algorithms found in the literature. It is shown that the proposed algorithm is robust against frequency selectivity and may therefore be used for sub channel SNR estimation. Throughput, route delay are also improved by using the proposed architecture**.

Keywords-OFDM, Encoder, Mapper, IFFT, Cyclic Prefix & Multipath Channel, Multi-hop,

I. Introduction

With the tremendous growth in demand for wireless Internet access and interactive multimedia services, next-generation wireless networks must support high-speed data rate. OFDM (orthogonal frequency division multiplexing) is one of the promising radio transmission technologies for future-generation broadband wireless networks. OFDM gains high speed transmission rate by transmitting data on several subcarriers at the same time and also it is robust to inter-symbol interference and frequency selective fading [1]. OFDM is currently used in high-speed wireless LAN (e.g., IEEE 802.11a) and fixed broadband access systems (e.g., IEEE 802.16a), and will be adopted widely in other wireless networks in the future. Generally, there are three multiple access schemes for OFDM systems: OFDM/FDMA (also called OFDMA),OFDM/CDMA, and OFDM/TDMA. In OFDMA, each user is allocated a certain number of OFDM subcarriers, where the allocation of subcarriers can be either static or adaptive [2]. In OFDM/CDMA, every user transmits data on all OFDM subcarriers using his unique code sequence. In OFDM/TDMA, each user is allocated a certain number of time slots in some/all of the subcarriers. In OFDMA, by taking advantage of multiuser diversity the static/ adaptive subcarrier allocation is generally done according to the channel characteristics so that the allocation among the users is optimal. However, this scheme requires frequency synchronization and results in overhead because some subcarriers or time slots need to be allocated for control messages, especially, in the case of adaptive allocation. In OFDM/CDMA, although the transmission rate can be enhanced by using frequency diversity, multiple access interference among concurrent transmissions needs to be mitigated. Therefore, complicated power control mechanisms are necessary. However, in OFDM/TDMA the transmission quality does not suffer due to multiple access interference. OFDM/TDMA supports both incoherent and coherent modulation, and is relatively easier to implement. OFDM/TDMA is used in Wireless MAN-OFDM [3] air interface for broadband wireless access (BWA) based on IEEE 802.16 in the 2-11 *GHz* band. A MAC frame structure for OFDM/TDMA was proposed in [4] so that transmissions of small size messages can be scheduled in one frame to reduce the transmission overhead, and thereby, the MAC level efficiency can be improved. The concept of 1-cell reuse

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OFDM/TDMA system that employs subcarrier adaptive modulation was introduced in [5]. In [6], a scheme for time slot allocation in OFDM/TDMA TDD system was introduced in which, by using busy-tone broadcast and channel sensing, the capacity and spectral-efficiency can be improved. To analyze the packet-level quality of service (QoS) under bursty data transmission, the queuing performance needs to be investigated.

II.Resource Management in OFDM-Based Broadband Wireless Networks

In this section, we will briefly introduce resource management in OFDM-based broadband networks, including the system model, challenges and techniques of adaptive resource management, and related standardization activities.

A. Adaptive Resource Allocation Techniques in OFDM-Based Networks

The architecture of a downlink data scheduler with multiple shared channels for multiple users is observed in literature. OFDM provides a physical basis for the multiple shared channels, where the total bandwidth B is divided into K subcarriers. The OFDM signaling is time-slotted, and the length of each time slot is Ts. The base station simultaneously serves M users, each of which has a queue to receive its incoming packets. Let M = {1, 2, · · · ,M} denote the user index set. To achieve high efficiency, both frequency and time multiplexing are allowed in the whole resource. The scheduler makes a resource assignment once at every slot. OFDM-based networks offer more degrees of flexibility for resource management compared to single carrier networks. Taking advantage of knowledge of the CSI at the transmitter (base station), OFDM-based systems can employ the following adaptive resource allocation techniques:

• *Adaptive modulation and coding* (AMC): the transmitter can send higher transmission rates over the subcarriers with better conditions so as to improve throughput and simultaneously to ensure an acceptable *bit-error rate* (BER) at each subcarrier. Despite the use of AMC, deep fading at some subcarriers still leads to low channel capacity.

• *Dynamic subcarrier assignment* (DSA): the base station dynamically assigns subcarriers according to CSI or/and QoS requirements. Channel characteristics for different users are almost mutually independent in multiuser environments; the subcarriers experiencing deep fading for one user may not be in a deep fade for other users; therefore, each subcarrier could be in good condition for some users in a multiuser OFDM wireless network. Besides, frequency multiplexing provides fine granularity for resource allocation.

• *Adaptive power allocation* (APA): the base station allocates different power levels to improve the performance of OFDM-based networks, which is called multiuser water filling. Employing these adaptive techniques at each subcarrier results in a large control overhead. In practice, several subcarriers can be grouped into a cluster (sub-channel), in which we apply those adaptive techniques. The size of a cluster determines the resource granularity. Obviously, the resource allocation schemes or algorithms designed for a subcarrier-based adaptive OFDM system can be directly used in a cluster-based system.

The major issue is how to effectively assign subcarriers and allocate power on the downlink of OFDM-based networks by exploiting knowledge of the CSI and the characteristics of traffic to improve spectral efficiency and guarantee diverse QoS. Three main challenges for cross-layer design for resource management in OFDM-based networks are present as follows:

• DSA belongs to the matching or bin packing problems in discrete optimization, which are mostly NP-hard or NP-complete.

• Unlike a single-carrier network, a multicarrier network can serve multiple users at the same time; hence, the design of multicarrier scheduling for bursty traffic is a new and interesting problem.

• The general relationship among spectral efficiency, fairness, and the stability property of wireless scheduling are not clear for wireless networks with time-varying fading.

All above problems are crucial for establishing high-speed and efficient wireless Internet networks.

B. Standardization Activities

OFDM is already widely adopted in IEEE 802.11 *wireless local area networks* (WLANs) and the digital audio and video broadcasting systems in Europe. However, these standards do not support frequency multiplexing for multiple access. The IEEE 802.16 standard [6], which is developed for *broadband wireless access* (BWA) networks, specifies two flavors of OFDM systems: OFDM and *OFDM access* (OFDMA). In the OFDMA mode, 1536 data subcarriers out of 2048 ones are equally divided into 32 sub-channels, which can be assigned to different users. Thus, DSA is an important function for improving the efficiency of resource allocation in the OFDMA mode. Note that the standard only specifies the system structure to guarantee inter-operability among multiple vendors' equipment and allows them to differentiate their equipment. In summary, the IEEE 802.16 standard supports DSA, but the details of DSA and scheduling algorithms are left unstandardized for vendors' selection. Therefore, advanced resource management and scheduling are a crucial part that determines the spectral efficiency and the QoS capability of equipment from different vendors.

III Queuing Systems

A queuing system consists of one or more servers that provide service of some sort to arriving customers. Customers who arrive to find all servers busy generally join one or more queues (lines) in front of the servers, hence the name **queuing systems**. There are several everyday examples that can be described as queuing systems [7], such as bank-teller service, computer systems, manufacturing systems, maintenance systems, communications systems and so on.

Components of a Queuing System: A queuing system is characterized by three components:

Arrival process - Service mechanism - Queue discipline.

A) Arrival Process

Arrivals may originate from one or several sources referred to as the **calling population**. The calling population can be limited or 'unlimited'. An example of a limited calling population may be that of a fixed number of machines that fail randomly. The arrival process consists of describing how customers arrive to the system. If A_i is the inter-arrival time between the arrivals of the (i-1)th and ith customers, we shall denote the mean (or expected) inter-arrival time by E(A) and call it **(λ);** = 1/(E(A) the arrival frequency.

b)Service Mechanism

The service mechanism of a queuing system is specified by the number of servers (denoted by s), each server having its own queue or a common queue and the probability distribution of customer's service time. Let S_i be the service time of the ith customer, we shall denote the mean service time of a customer by E(S) and **µ** = 1/(E(S) the service rate of a server.

c) Queue Discipline

Discipline of a queuing system means the rule that a server uses to choose the next customer from the queue (if any) when the server completes the service of the current customer. Commonly used queue disciplines are:

FIFO - Customers are served on a first-in first-out basis. LIFO - Customers are served in a last-in first-out manner. Priority - Customers are served in order of their importance on the basis of their service requirements.

d) Measures of Performance for Queuing Systems:

There are many possible measures of performance for queuing systems. Only some of these will be discussed here.

Let, D_i be the delay in queue of the ith customer W_i be the waiting time in the system of the ith customer = $D_i + S_i$ Q(t) be the number of customers in queue at time t L(t) be the number of customers in the system at time t = Q(t) + No. of customers being served at

Then the measures,

$$d = \lim_{i \to m} \frac{\sum_{i=1}^{i-2} D_i}{n} \quad \text{and}$$

$$w = \lim_{i \to m} \frac{\sum_{i=1}^{i-2} W_i}{n} \qquad \text{Eq(1)}$$

(if they exist) are called the **steady state average delay** and the **steady state average waiting time in the system**. Similarly, the measures,

$$Q = \lim_{T \to m} \frac{1}{T} \int_0^T Q(t).dt \quad \text{and}$$

$$L = \lim_{T \to m} \frac{1}{T} \int_0^T L(t).dt \qquad \text{Eq(2)}$$

(if they exist) are called the **steady state time average number in queue** and the **steady state time average number in the system.** Among the most general and useful results of a queuing system are the **Conservation equations**:

$$Q = (\lambda)d \text{ and } Q = (\lambda)d \qquad \text{Eq(3)}$$

These equations hold for every queuing system for which d and w exist. Another equation of considerable practical value is given by,

$$w = d + E(S) \qquad \text{Eq(4)}$$

Other performance measures are:

the probability that any delay will occur. - the probability that the total delay will be greater than some pre-determined value - that probability that all service facilities will be idle. - The expected idle time

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of the total facility. - The probability of turn-always, due to insufficient waiting accommodation.

e) Notation for Queues:

Since all queues are characterized by arrival, service and queue and its discipline, the queue system is usually described in shorten form by using these characteristics. The general notation is:

[A/B/s]:{d/e/f}

Where,

A = Probability distribution of the arrivals

B = Probability distribution of the departures

s = Number of servers (channels)

d = The capacity of the queue(s)

e = The size of the calling population

f = Queue ranking rule (Ordering of the queue)

There are some special notation that has been developed for various probability distributions describing the arrivals and departures. Some examples are,

M = Arrival or departure distribution that is a Poisson process

E = Erlang distribution

G = General distribution

GI = General independent distribution

Thus for example, the **[M/M/1]:{infinity/infinity/FCFS}** system is one where the arrivals and departures are a Poisson distribution with a single server, infinite queue length, calling population infinite and the queue discipline is FCFS. This is the simplest queue system that can be studied mathematically. This queue system is also simply referred to as the M/M/1 queue.

IV System Model Requirements (Markovian System)

The common characteristic of all markovian systems is that all interesting distributions, namely the distribution of the inter arrival times and the distribution of the service times are exponential distributions and thus exhibit the markov (memory-less) property. From this property we have two important conclusions:

- The state of the system can be summarized in a single variable, namely the number of customers in the system. (If the service time distribution is not memory-less, this is not longer true, since not only the number of customers in the system is needed, but also the remaining service time of the customer in service.)
- Markovian systems can be directly mapped to a *continuous time markov chain* (CTMC) which can then be solved.

A. The M/M/1-Queue

The M/M/1 Queue has iid inter-arrival times, which are exponentially distributed with specified parameters and also iid service times with exponential distribution. The system has only a single server and uses the FIFO service discipline. The waiting line is of infinite size. It is easy to find the underlying markov chain. As the system state we use the number of customers in the system. The M/M/1 system is a pure birth-/death system, where at any point in time at most one event occurs, with an event either being the arrival of a new customer or the completion of a customer's service. What makes the M/M/1 system really simple is that the arrival rate and the service rate are not state-dependent.

Steady-State Probabilities

We denote the steady state probability that the system is in state k(k€N) by pk, which is defined by

$$p_k := \lim_{t\to\infty} P_k(t) \qquad \text{Eq(5)}$$

Pk(t) Where pk(t)) denotes the (time-dependent) probability that there are k customers in the system at time tt. Please note that the steady state probability pk does not dependent on t. We focus on a fixed state k and look at the *flows* into the state and out of the state. The state k can be reached from state k-11 and from state k+1,1 with the respective rates $\lambda P_{k-1}(t)$ (t) (the system is with probability $P_{k-1}(t)$ (t) in the state k-1 at time t t and goes with the rate λ _ from the predecessor state k-11 to state k k) and $\mu P_{k+1}(t)$ (the same from state k+1). The total flow into the state k k is then simply $\lambda P_{k-1}(t)+\mu P_{k+1}(t)$. The State k k is left with the rate $\lambda P_k(t)$) to the state k+1 and with the rate $\mu P_k(t)$ (t) to the state k-11 (for k=00 there is only a flow coming from or going to state 1). The total flow out of that state is then given by $\lambda P_k(t)+\mu P_k(t)$. The total rate of change of the flow into state k is then given by the difference of the flow into that state and the flow out of that state:

$$\frac{dP_k(t)}{dt} = (\lambda P_{k-1}(t)+\mu P_{k+1}(t)) - (\lambda P_k(t)+\mu P_k(t)) \qquad \text{Eq(6)}$$

Furthermore, since the pk are probabilities, the *normalization condition*

$$\sum_{k=0}^{\infty} p_k = 1 \qquad \text{Eq(7)}$$

B. M/M/m-Queue

The M/M/m-Queue (m > 1) has the same inter-arrival time and service time distributions as the M/M/1 queue, however, there are m servers in the system and the waiting line is infinitely long. As in the M/M/1 case a complete description of the system state is given by the number of customers in the system (due to the memory-less property). The M/M/m system is also a pure birth-death system.

C. M/M/1/K-Queue

The M/M/1/K-Queue has exponential inter-arrival time and service time distributions, each with the respective parameters λ and μ. The customers are served in FIFO-Order; there is a single server but the system can only hold up to K customers. If a new customer arrives and there are already K customers in the system the new customer is considered lost, i.e. it drops from the system and never comes back. This is often referred to as *blocking*. This behavior is necessary, since otherwise (e.g. when the customer is waiting outside until there is a free place) the arrival process will be no longer markovian. As in the M/M/1 case a complete description of the system state is given by the number of customers in the system (due to the memory-less property). The M/M/1/K system is also a pure birth-death system. This system is better suited to approximate "real systems" (like e.g. routers) since buffer space is always finite.

V Comparison Of Different Queuing Models

In this section we want to compare three different systems in terms of mean response time (mean delay) vs. offered load: a single M/M/1 server with the service rate mμ, a M/M/m system and a system where m queues of M/M/1 type with service rate μ are in parallel, such that every customer enters each system with the same probability. The answer to this question can give some hints on proper decisions in scenarios like the following: given a computer with a processor of type X and given a set of users with long-running number cruncher programs. These users are all angry because they need to wait so long for their results. So the management decides that the computer should be upgraded. There are three possible options:

- buy n-1 additional processors of type X and plug these into the single machine, thus yielding a multiprocessor computer
- buy a new processor of type Y, which is n times stronger than processor X and replacing it, and
  let all users work on that machine
- provide each user with a separate machine carrying a processor of type X, without allowing
  other users to work on this machine

We show that the second solution yields the best results (smallest mean delays), followed by the first solution, while the last one is the worst solution. The first system corresponds to an M/M/m system, where each server has the service rate μ and the arrival rate to the system is λ. the second system corresponds to an M/M/1 system with arrival rate λ and service rate m.μ. And, from the view of a single user, the last system corresponds to an M/M/1 system with arrival rate λ/k and service rate μ. These mathematical, probabilistic markovian models is applied at the channel side for better channel allocation. Once the channel is allocated effectively the snr estimation is done at the receiver side by the proposed estimator to have good performance of the system.

Proposed estimator

A new estimator based on periodically used subcarriers is explored in this section, named PS estimator in the following. Orthogonal frequency division multiplexing (OFDM) offers high data rates and robust performance in frequency selective channels by link adaptation utilizing information about the channel quality. A crucial parameter required for adaptive transmission is the signal-to-noise ratio (SNR). In this work, we propose a novel SNR estimation algorithm for wireless OFDM systems based on the reuse of the synchronization preamble as well best channel allocation scheme using queuing theory. The periodic structure of the preamble is utilized for the computationally efficient SNR estimation algorithm, based on the second-order moments of received preamble samples. The performance of the proposed algorithm is compared with the MMSE algorithm and two preamble-based algorithms found in the literature. It is shown that the proposed algorithm is robust against frequency selectivity and may therefore be used for sub-channel SNR estimation. And by using queuing theory the channel allocation is done properly by controlling the arrival as well as service rates. By proposing these two concepts obviously the systems throughput as well quality of service improvises.

The key idea rests upon the time domain periodic preamble structure for time and frequency synchronization in [4]. In order to cover a wider frequency range, in [3] a preamble of Q identical parts, each containing N/Q samples is proposed as depicted in Fig. 2a. The corresponding frequency domain representation is shown in Fig. 2b. In the sequel we assume that Q divides N, so that $Np = N/Q$ is integer. Starting from the 0th, each Qth subcarrier is modulated with a QPSK signal

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$C_p(m), m = 0,1........., N_p - 1$. With $|C_p(m)| = 1$ The remainder of $N_z = N - N_p = \frac{(Q-1)}{Q} N$ subcarriers is not used (nulled). In order to maintain the total energy level over all symbols within the preamble, the power is scaled by factor Q yielding a total transmit power of SQ in the loaded subcarriers.

Write

$$n = mQ + q, m = 0,1...N_p - 1, q = 0,...., Q - 1$$

The transmitted signal on the nth subcarrier is written as

$$C(n) = C(mQ+q) = \begin{cases} C_p(m), q=0 \\ 0, q=1,.....Q-1 \end{cases} \quad \text{eq (8)}$$

By (1) the nth received signal is given by

$$Y(n) = Y(mQ+q) = \begin{cases} Y_p(m), q=0 \\ Y_z(mQ+q), q=1,.....Q-1 \end{cases}$$

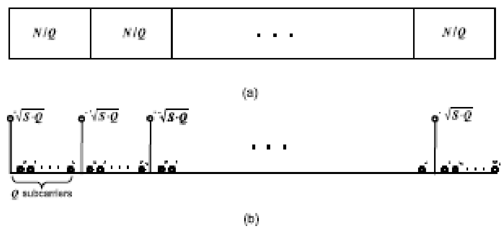

Figure 1: Preamble structure in (a) time and (b) frequency domain

Where

$$Y_p(m) = \sqrt{SQ}C(k,n)H(k,n) + \sqrt{W}\eta(k,n) \quad \text{eq(9)}$$

denotes the received signal on loaded subcarriers, and

$$Y_z(mQ+q) = \sqrt{W}\eta(mQ+q) \quad \text{eq(10)}$$

the received signal on nulled subcarriers consisting only of noise. The empirical second-order moment of loaded subcarriers is

$$\hat{M}_{2,p} = \frac{1}{N_p}\sum_{m=0}^{N_p-1}|Y_p(m)|^2 \quad \text{eq(11)}$$

Its expected value is given as

$$E\{\hat{M}_{2,p}\} = \frac{1}{N_p}\sum_{m=0}^{N_p-1}E\{|Y_p(m)|^2\}$$

$$= \frac{QS}{N_p}\sum_{m=0}^{N_p-1}E\{|H(m)|^2\} + \frac{W}{N_p}\sum_{m=0}^{N_p-1}E\{|\eta(m)|^2\}$$

$$= QS + W$$

Similarly, the empirical second moment of the received signal in nulled subcarriers

$$\hat{M}_{2,z} = \frac{1}{N_p(Q-1)}\sum_{m=0}^{N_p-1}\sum_{q=1}^{Q-1}|Y_p(mQ+q)|^2 \quad \text{eq(12)}$$

has expectation

$$E\{\hat{M}_{2,z}\} = \frac{1}{N_p(Q-1)}\sum_{m=0}^{N_p-1}\sum_{q=1}^{Q-1}E\{|Y_z(mQ+q)|^2\}$$

$$= \frac{W}{N_p(Q-1)}\sum_{m=0}^{N_p-1}\sum_{q=1}^{Q-1}E\{|\eta(mQ+q)|^2\}$$

$$= W$$

In summary, the average SNR ρav can be estimated by Forming

$$\hat{\rho}_{av} = \frac{1}{Q}\frac{\hat{M}_{2,p} - \hat{M}_{2,z}}{\hat{M}_{2,z}}$$

$$= \frac{1}{Q}\left((Q-1)\frac{\sum_{m=0}^{N_p-1}|Y_p(m)|^2}{\sum_{m=0}^{N_p-1}\sum_{q=1}^{Q-1}|Y_z(mQ+q)|^2} - 1\right) \quad \text{eq(13)}$$

VI. Results

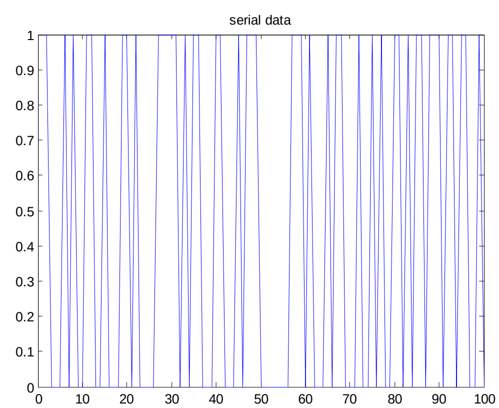

Figure 1: Serial data

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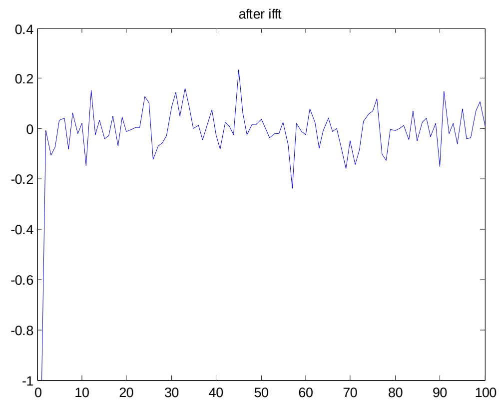

Figure 2: After IFT

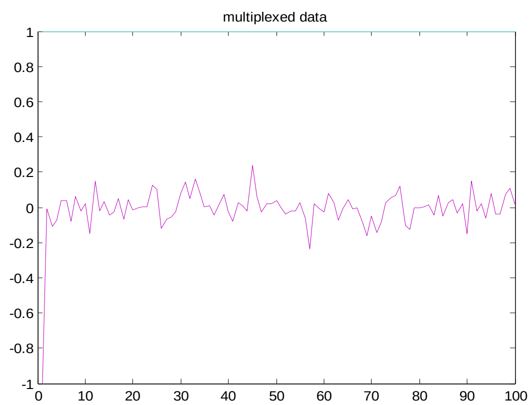

Figure 3: Multiplexed data

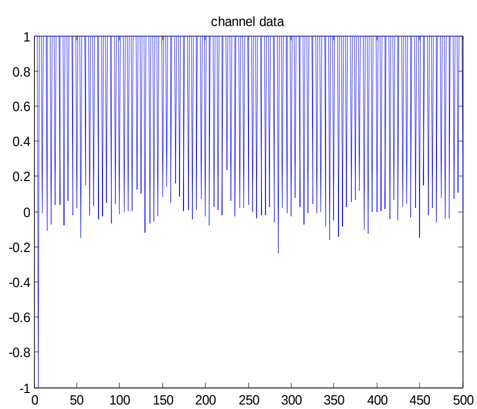

Figure 4: Channel data

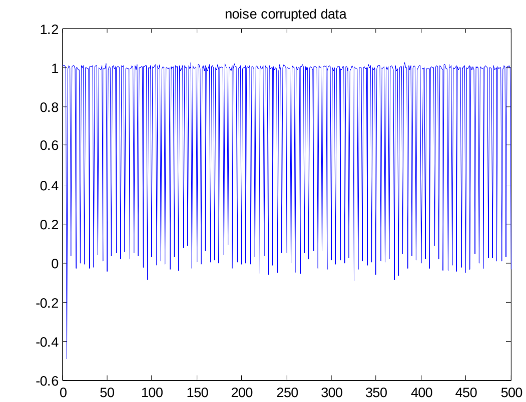

Figure5: NOise corrupted data

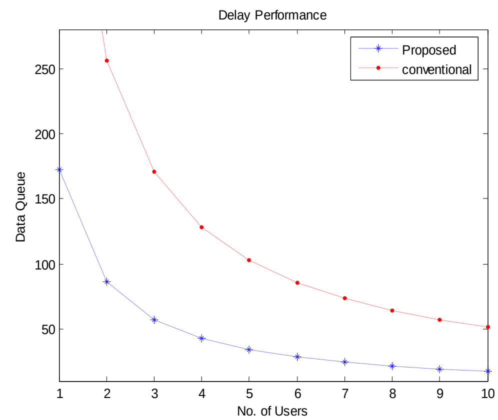

Figure6: Delay performance

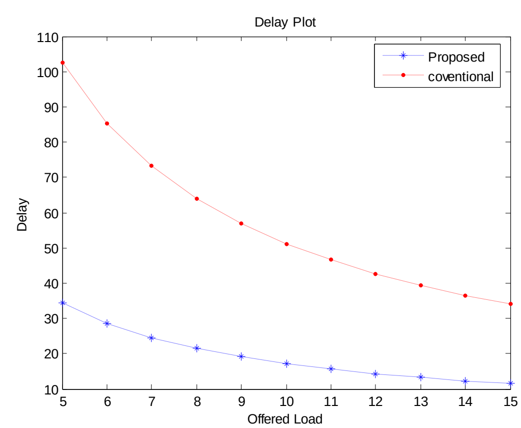

Figure7: Delay plot

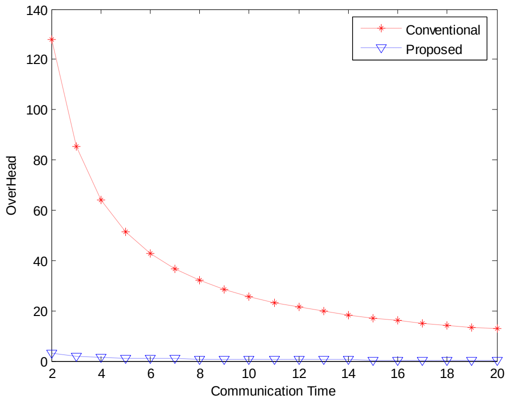

Figure8:

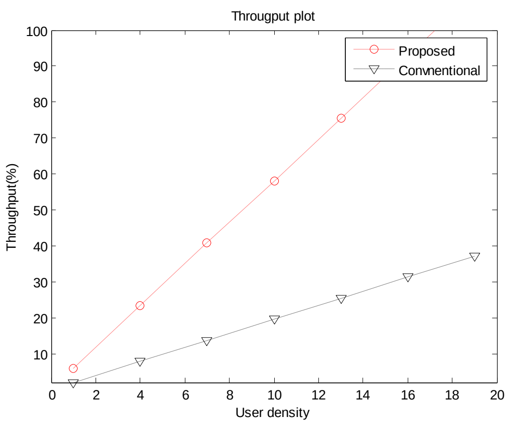

Figure9: Throughput plot

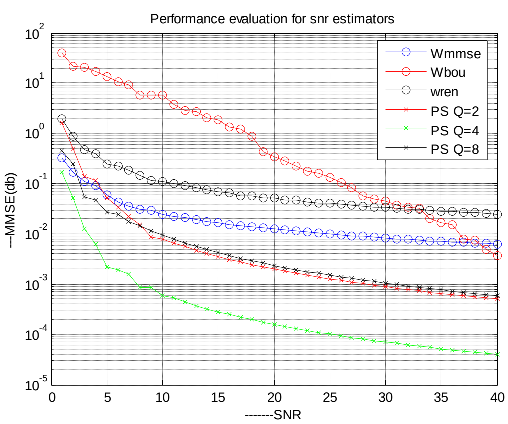

Figure 10 NMSE of the average SNR in AGN channel

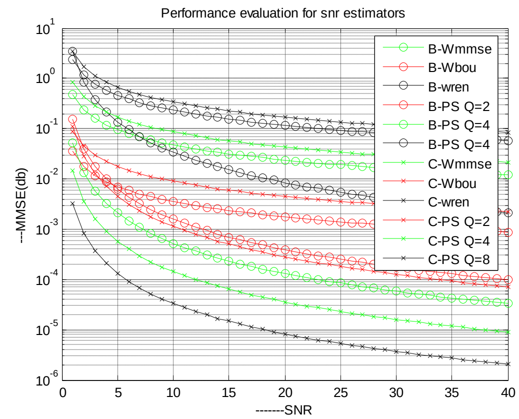

Figure 21: NMSE of the average SNR in channel (b) and(c)

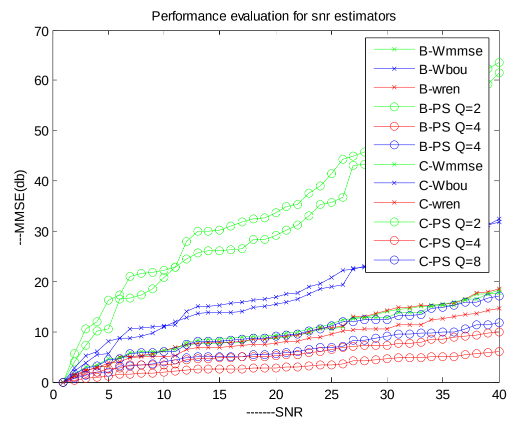

Figure 3: Mean of the estimated average SNR in channel (b) and(c)

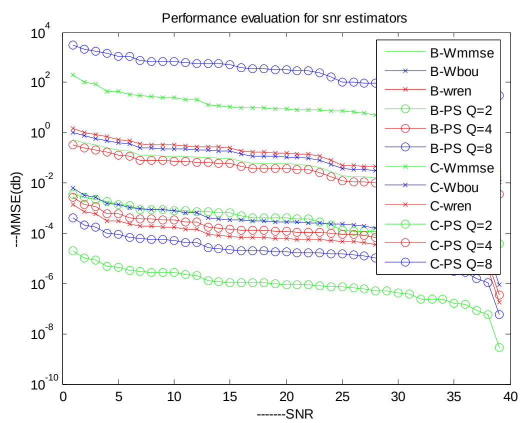

Figure 4: NMSE of the average SNR per subcarrier in channel(b)and(c)

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VII. Conclusion

We proposed a multiclass multi-server batch arrival queuing system at the channel level for the performance analysis in the context of OFDM subcarrier allocation in future generation OFDM-based wireless multiservice networks. And also a novel preamble-based SNR estimator for wireless OFDM systems has been proposed. Reuse of the synchronization preamble for the SNR estimation purposes by exploiting its time domain periodic Structure puts no additional overhead on transmitted OFDM frame. Increasing the number of repeated parts by nulling the subcarriers on specified positions improves the performance of considered estimator, but also increases its sensitivity to frequency selectivity. Low complexity and robustness to frequency selectivity combined with the bandwidth efficiency favors the proposed estimator compared to the considered preamble-based estimators given in the literature.

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