Insights of Bit-Loading Algrorithms for Effective Resource Allocation in Wireless Networks

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Abstract— Resource allocation is one of the most essential operations in multicarrier wireless communication system. Although wireless networking technologies have been constantly improving but still there are various problems associated with the performance of resource allocation schemes over the wireless nodes that degrades the system efficiencies. This paper reviews all the significant studies of resource allocation schemes being introduced in last decade towards bit-loading algorithm in order to understand the effectiveness of the existing system with respect to next generation wireless networking system. The paper performs a critical evaluation of the essential techniques of bit-loading algorithms and power-allocation algorithm individually along with the combined study of joint implementation too. The paper contributes to identify the critical research gap for the existing literatures in order to highlight the need of the system improvement in wireless networks.

Index Terms— Bit-Loading Algorithm, Modulation, Multicarrier Wireless Communication, Power Allocation Algorithm, Resource Allocation, Spectrum, Wireless Network.

1 Introduction

The area of wireless communication system has constantly been the attention point among the researchers as well as its users too. Owing to less maintenance, cost effectiveness, and effective support to mobility wireless network has gained its technical adoption. Moreover with the parallel improvement in mobile network and mobile computing, the users are increasingly exploring various means to use the wireless networks. As there are numerous reasons for technical adoption of wireless communication system, there are also some issues associated with it [1] [2] [3]. 2G has now become history and so is 3G if we speak about usage of mobile networks as wireless system. However, usage of 3G has still not met the anticipated number of customers in many countries owing to certain technical constraints. Although such technical constraints are not eliminated, there is an evolution of 4G/LTE based mobile networks. However, question arises is - does this type of wireless network has fully overcome the technical challenges. The answer will be no if asked to majority of the mobile services users. An in-depth study of wireless network shows that such type of network uses multicarrier modulation scheme in order to accomplish maximized rate of data transmission [4]. One such example is OFDM (Orthogonal Frequency Division Multiplexing) system, which allocates discrete task to numerous subcarriers to increase the data rate [5]. One of advantage of such modulation scheme is its supportability of data transmission over minimal rate for each subcarrier at a same time. Still now, conventional modulation schemes are applied over such wireless network that uses the similar constellation of signal for all the subcarrier signals. Adoption of such scheme will essentially result in bad bit error rate (BER) performance. Hence, the alternative solution is to apply the concept called as bit loading. Bit-loading concept uses constellation of signal over various available subcarriers [6]. In existing system, certain numbers of the subcarriers are sometimes switched off in case the Signal-to-Noise ratio (SNR) values of the particular subcarrier are found to be extremely poor. Majority of the existing studies till date considers the predefined knowledge of the SNR data of the subcarriers with 100% accuracy and then it applies adaptive bit-loading technique. Although outcomes of such approaches may seem to be good, a closer investigation on such outcome will show unreliability factor. The prime reason behind this is such approaches don't consider various forms of assumptions and dependencies (or constraint formulation) that should have characterized the essential features of that traffic in wireless network. We don't discredited the existing work is not up to the mark, but we state that existing studies are perform without consideration of various original facts. One of such fact is failure to visualize the actual requirement of next generation wireless standards.

The contribution of this paper is to elaborate about the research attempts towards design and development of existing bit loading algorithms in wireless system. At present, there is no survey or review work being done till date to critically assess the research attempts of last 10 years pertaining to the topic of bit-loading algorithm. Our another contribution is to measure the effectiveness of the most significant work done in last 10 years with exploration of critical research gap. Section II discusses about the fundamental essentials of bit-loading algorithm followed by existing research work on it in Section 3. Section 4 discusses about the fundamental essentials of power allocation algorithms followed by existing research work being carried out in it Section 5. Studies on combined implementation of bit-loading algorithms and power allocation scheme are discussed in Section 6. This section also discusses about the existing technique, performance parameters, and outcome assessment more critically. Section 7 discusses about the network specific studies. Section 8 discusses about the research gap explored followed by conclusion in Section 9.

2 Essentials of Bit-Loading Algorithm

The concept of bit loading starts from wireless communication system. While performing communication, it is quite important to understand the pattern of the data (or bits) being com-

municated from transmitter to receiver. Usually wireless network for present era uses subcarriers to transmit data packet. Hence, bit loading is a phenomenon that is used for evaluating the precise amount of data (or bits) that can be transmitted over the subcarriers. It is said that system performance is highly enhanced when the transmission is carried out over different quantity of data on numerous subcarriers. The core concept of bit-loading algorithms mainly concentrates on i) bit rate of the subcarriers as well as ii) characteristics of channel. In majority of the existing study, which will be discussed in this paper, it was seen that bit-loading algorithms are normally for its effectiveness with respect to performance parameters e.g. bit error rate, rate of data transfer, and cumulative power to transmit a data [7]. Such studies have adopted Signal-to-Noise Ratio (SNR) for estimating quantity of transmitted bits on each subcarrier. Interestingly, the value of SNR can highly fluctuate from one to another user on a common subcarrier [8]. The standard concept of Shannon's theory stated the amount of data per second on every frequency (bps/Hz) could be accomplished from subcarriers possessing maximum value of SNR [9]. Hence, in a nutshell, it can be stated that data rate as well as utilization of channel can be highly enhanced for wireless network using the concept of bit-loading algorithms. Studies on bit-loading algorithms has also seen two types of it e.g. margin-based technique and rate-based technique. The margin-based bit-loading algorithm [10] is responsible for reducing the transmittance power based on the constraints imposed over bit error rate and data rate. The rate-based bit-loading algorithm is responsible for increasing the rate of data transfer imposed over bit error rate and power constraints [11].

In order to implement the concept of bit-loading algorithms, there are few basic requirements that must be compliant on the wireless network as:

- The system should have instantaneous access on the information about the channel for executing bit-loading algorithms. Normally, this is achieved by transmitting a test signal at periodic intervals.
- The system (transmitter/receiver) should have better supportability of numerous modulation techniques over wireless environment.

The frequently adopted algorithms for bit-loadings are i) Chow-Leke-Cioffi scheme [12], ii) Fischer-Huber Scheme [13], and iii) Hughes-Hartogs Scheme [14]. The first scheme is no more effective as seen from the study of many researchers, while the last scheme is characterized with enhanced SNR performance comparatively. However, with the evolution of advancement in the research work in wireless network for resource allocation, there has been a significant and continuous studies towards bit loading algorithm. The next section will discuss about the most significant research attempts for mitigating the problems of bit-loading algorithms.

3 Existing Research Work in Bit Loading Algorithm

This section will discuss about the existing research work being conducted to sort out the issues in bit-loading algorithms. The discussion is based on collection of 20 most significant literatures ranging from the year 2004 till 2015.Wyglinski et al. [15] have investigated about the robustness of numerous bit loading algorithms. The study discussed that perfectness of SNR value is highly important while deploying bit-loading algorithm. The outcome of the study shows imperfect SNR minimizes throughput for adaptive bit-loading algorithm.

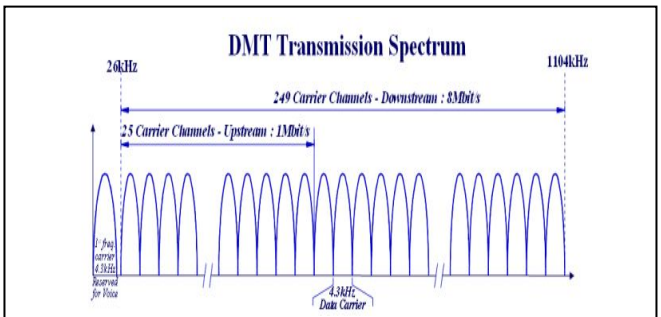

Fig. 1 **T**ransmission Spectrum of DMT

Filho et al. [20] have presented a bit-assignment technique to mitigate an event of crosstalk by enhancing the rate of data transfer for available power. The study focused on precoded DSL system that allocates a number of integer types to each data resulting in increasing bit rates. Liu and Mathar [21] have studied about the OFDM network considering defective Channel State Information (CSI). The work done is enhanced over water-filling process for increasing the data rate. The simulation study is done by modeling frequency selective channel with multiple Rayleigh paths. The outcome of the study shows the level of impact of BER on parameters considered for study. Zhuang et al. [22] have studied bit allocation technique for cognitive radio network and presented an algorithm for allocating resources for both primary and secondary users considering interference factor too. The outcome of the study is designed considering capacity and transmission rate mainly. Most recently, Vo et al. [23] have used a novel bit loading algorithm considering spectral mask and energy constraints. The system has been designed by enhancing the conventional water filling algorithm. The outcome of the study was evaluated using cumulative run-time and total number of operation being carried out on increasing number of subcarriers to see the system can solve the bit loading problem.

4 Essentials of Power Allocation Algorithm

The increased use of wireless network as a part of pervasive computing, which demands system owing to its potential supportability of the data as well as voice-based seamless services. However, there are critical challenges in doing so. For the target of catering up the maximizing requirements of the data rate, the existing technologies are adopting high speed wired network using reconfigurable networks or optical links

[24]. It is essentially significant to completely exploit the available capacity of the wireless system along with the equal concern for designing a fail-proof and fault tolerant communication system that integrated various types of networking system. With the extensive proliferation of microprocessor-based system, the devices in the wireless networking are becoming smarter with extended capability to process sophisticated computation. Various forms adaptive coding schemes are also used for this purpose to enhance the processing capability of the system. And all these happen with the cost of power. Hence, power factor plays a significant role in performance of wireless network.

The wireless node can actually forward the bits to numerous communication channels at a same time (e.g. OFDM system) by allocating a specific and appropriate level of power to the subcarriers for each node pairs. A power matrix is designed for this purpose recording the cumulative constraints of the power for all the nodes [25]. The rate of transmission could be evaluated using allocation matrix for power as well as updated CSI data. Usually, in such cases a controller is designed for the purpose of allocating power as well as provisioning data to be transmitted over the communication channel in response to the CSI data and traffic load data. The primary aim of such controller design will be to maintain equilibrium of the system as well as accomplish optimal QoS.

Normally the nodes in the wireless network system are sustained by the limited power supply and hence they suffer from faster energy dissipation too. Faster dissipation of power will also affect the communication system drastically. Therefore, power allocation problem is also one of the unsolved problems in the research community. The design of the existing power allocation algorithms are mainly motivated to accomplish distribution of power available to all the users and sub-channels optimally. However, both rate as well as power attribute are considered for accomplish this task. Finally, the optimal distribution of the power is subjected to transformation for extracting the appropriate cases of data rate over each subcarrier. The objective function of the optimization technique calls for a design of rate factor enhancement (Rmax) as well as reduction in power factor (Pmin) considering the available constraints. Therefore, using this fact, majority of the existing system attempts formulation of the bit-loading as well as power allocation problem considering the constraints of power budgets.

Considering the fact that ρ denotes the cumulative budge of power and γ represents anticipated rate of data transmission. Hence the problem of R_{max} and P_{min} can be mathematically represented as,

i) R_{max} Problem (bit-loading problem): The problem formulation of maximum data rate is,

$$\max \sum_{i=1}^{N} \log_2(1+P_i.g_i)$$

Subjected to $\sum_{i=1}^{N} P_i \le \rho, P_1 \ge 0, \forall i: 1 \le i \le N$

ii) P_{min} Problem (power allocation problem): The problem formulation of minimum power allocation is,

$$\min \sum_{i=1}^{N} \frac{2^{b_i}-1}{g_i}$$

Subjected to $\sum_{i=1}^{N} b_i = \rho, b_i \ge 0, \forall i: 1 \le i \le N$

It can be seen from the mathematical expression that logarithmic representation of Rmax is in increasing order and also concave function of Pi. However, the same for the Pmin is again witnessed with increasing pattern as well as convex function of bi. Therefore, it is known that Rmax and Pmin essentially fits in to the category of convex optimization problem with given set of convex constraints. This is also one of the reasons of existence of uniqueness in its global solution. A closer look into both Rmax and Pmin will show that problems of rate maximization and power minimization are a non-linear problem.

5 Existing Research Work in Power Allocation Algorithm

This section will brief about the existing research towards power allocation algorithm particularly focusing on wireless networks. The significant 20 literatures ranging from 2013 to 2015 are discussed. The study conducted by Han et al. [26] have emphasized on the power allocation factor on OFDM network with multi users. The authors have solved the optimization problem considering pairing, assigning, and power allocation of subcarriers in OFDM system using network coding. Huang et al. [27] have investigated about the issues of power allocation on cellular network considering multimedia streaming over variable bit rate. The study has tagged the problem as non-convex optimization problem. Similar direction of the study was also carried out by Ahmed et al. [28]; however, the focus was on cognitive radio network. The authors have presented an optimization technique of distributed nature in order to control the power allocation strategies on cognitive network. Deepa and Rajkumari [29]have presented a scheme to allocate power for multi-users in OFDM as well as in cognitive radio network. Dikmese et al. [30] have adopted techniques based on filter-bank in cognitive networks for power allocation. The authors have designed an algorithm that maximizes the link capacity of the secondary user considering jointly interference and power constraints. Elnaby et al. [31] have presented another study for power allocation in OFDM system using gain based algorithm. The outcome of the study was evaluated using throughput. Study towards OFDMA networks was carried out by Ha et al. [32] Towards power allocation system. The presented solution was based on low-complexity algorithm design of distributed nature. The outcome of the study was evaluated using performance parameters of mean fairness index, cumulative spectral efficiency. A significant study on sharing OFDM spectrum for power allocation was seen in the work carried out by Zhang et al. [33]. Different from all the techniques till date in studied of

power allocation; this technique has used game theory to achieve more optimal performance in power allocation for both multi primary and secondary users. Similar category of work is also carried out by Vinh et al. [34] and Yao et al. [35]. However, Yao et al. [35] have introduced a unique feature of network called as machine-to-machine network. It is basically based on power allocation scheme on cognitive networks.

6 Combined Studies

The prior sections of this paper have discretely discussed 40 significant studies focusing on unique implementation of bit-loading algorithms (in Section 4) and power-allocation algorithm (in Section 5) pertaining to wireless network. However, there are also certain set of work that has considered jointly both the above problems of resource allocation. This section will discuss some of the significant literatures that were found to jointly address the problems associated with bit-loading algorithms as well as power-allocation algorithms. Study in this direction was dated back on 2003, where a significant work of Daly et al. [36] has been witnessed. The authors have emphasized the dependency on nonlinear programming for performing both bit-loading as well as ensuring efficient power allocation in multitone systems. A typical multitone system is exhibited in Fig.2 that generally consists of orthogonal filters for synthesis along with their filter banks. Equalization of the tone is performed for minimizing the orthogonality of the channel as well as retaining each tone in narrowband. Different forms of basic functions are used for this purpose e.g. FFT is used in DMT, while cosine-based modulation technique using low-pass filter is used in wavelet based DMT. The system model designed by Daly et al. [36] Consists of multitone communication system and pulse amplitude modulation mainly. The simulation study carried out consists of using asynchronous DSL based communication. The outcome of the study was evaluated on 8 different test loops to highlight the enhanced bit loading system with enhanced power allocation techniques.

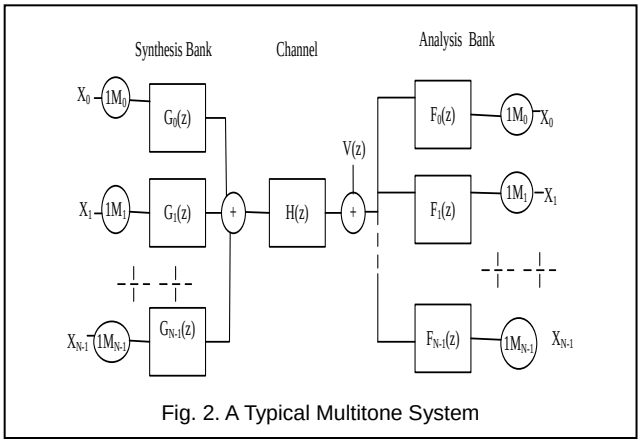

Fig. 2. A Typical Multitone System

The study conducted by Papandreou and Antonakopoulos [37] have investigated about the critical condition responsible for maximizing rate as well as margin. The author has also studied various bit-loading techniques. Study presented by Guerrini et al. [38] has discussed about the technique to enhance the communication performance. The author has named it as HomePlug designed exclusively for frameworks of power line channel. The authors have used rate adaptive technique for allocation of power uniformly using DLC based bit – loading system. DLC will stand for decreasing log-likelihood ratio (LLR) constraint for power allocation. The study is done over OFDM channel using turbo coding approach especially targeting on SISO. The outcome of the study was evaluated with respect to throughput and multiple modulation technique mainly. Fig.3 will highlight the comparative analysis of the DLC-based technique of Guerrini et al. [38] And BER Threshold Constraint (BTC) based technique.

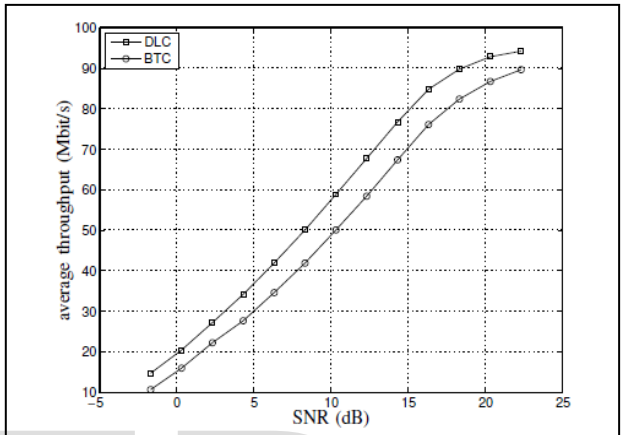

Fig.3. Outcome of work done by Guerrini et al. [38].

Shen et al. [39] have introduced an algorithm capable of enhancing the capacity of the channel with retention of fairness index and considering uniform distribution of power over OFM system. The system is designed considering multi-users in OFDM. Fairness index is introduced in the system for ensuring better control over the capacity among different users in OFDM. The optimization modelling in this work also considers the conditions to meet the anticipated data rate for all the users in OFDM system. The mathematical formulation of capacity (R) is modelled by author as (in equation 1),

$$R_k = \sum_{n=1}^{N} \frac{\rho_{k,n}}{N} \log_2 \left(1 + \frac{p_{k,n} h_{k,n}^2}{N_o (B/N)} \right) \quad (1)$$

The modelling considers N as cumulative sub-channels and No as power spectral density, B as bandwidth, p as allocated power for users and ρ is sub-channel. The author has also formulated an equation for evaluating fairness index of the sub-channels as,

$$F = \left(\sum_{k=1}^{K} \gamma_k \right)^2 / K \sum_{k=1}^{K} \gamma_k^2 \quad (2)$$

Eq.(2) shows the formulation of fairness index where the variable γ is a value that is predetermined for ensuring uniform fairness among the multi-users in OFDM system. The outcome of the study was evaluated using capacity and throughout, where capacity was the prime focus of the author.

Fig.4 highlights the outcome where the authors have compared its outcome with capacity achieved by Jang and Lee [40].

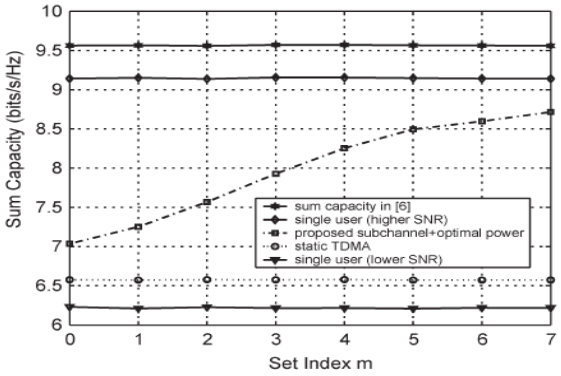

Fig.4. Outcome of work done by Shen et al. [39]

The study outcome was also compared with static TDMA system and on multiple user environments in OFDM. The performance of this model was found to be 95% compared to its comparative attributes.

Wang et al. [41] have enhanced the conventional Fisher and Huber bit loading algorithm in order to ascertain consistent communication performance over power line communication. The authors have initially evaluated dynamic range of the transmission coefficients of subcarriers and the performed estimation of the cost with respect to the allocated power for each user. The authors have explored that conventional bit loading algorithms doesn't have consideration of impact of over-allocated data from the condition of turning off subcarriers. The technique presented by the author have initially deploys an additional vector to trace the subcarriers that are about to allocate over amount of bits. The system than remove such subcarriers in the next cycle. The system only considers the subcarriers with rate of positive value.

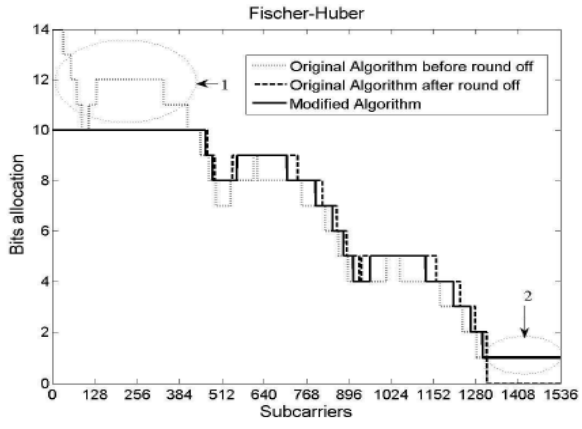

Fig.5. Bit allocation of work done by Wang et al. [41]

The outcome of the study is shown in Fig.5 and Fig,6 for bit allocation performance and for BER performance respectively. The comparative analysis is done with original Fischer and Huber algorithm with the modified one.

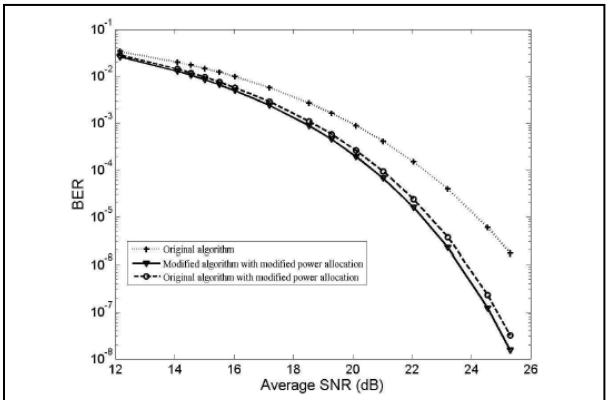

Fig.6. BER Performance of work done by Wang et al. [41]

The outcome of the study shows enhancement in performance improvement as compared to the conventional bit loading algorithms. However, the system is also accompanied with complexity. Sudhir et al. [42] have carried out the work on bit allocation for OFDMA system focusing on the multicarrier. The primary study aims to minimize the cumulative power required for transmittance in order to cater up physical and application layer requirements in OFDMA.

The study conducted by Nadkar et al. [43] is one of the most standard studies till date concerning about bit-loading and power allocation in cognitive networks. The technique has considered classifying the primary user in the forms of various sub-bands for the purpose of ascertaining minimized interference level for every user. For this purpose, the authors have implemented around 5 algorithms,

- *Algorithm-1*: It is basically designed based on iterative technique to accomplish the power allocation objective under interference and power constraints.
- *Algorithm-II*: It is meant for using greedy approach minimizing the computational complexity involved in the process owing to iterative nature of *Algorithm-1*.
- *Algorithm-III*: This algorithm is responsible for initializing the bit-loading algorithm as well as simultaneously computation of the power allocation in presence of interference.
- *Algorithm-IV*: This algorithm is responsible for ensuring the power as well as interference constraints.
- *Algorithm-V*: This algorithm initializes the bandwidth of the sub-carrier and evaluates the quantity of the available subcarriers. The algorithm also estimates the throughput for the subcarriers.
- *Algorithm-VI*: This algorithm computes the best allocated power as well as bandwidth of subcarrier. Finally, the algorithm computes the number of data (or bits) to be loaded.
- *Algorithm-VII*: This algorithm adopts Lagrangian multiplier for evaluating the optimal power to be allocated for every subcarrier.

- *Algorithm-VIII*: This algorithm will compute the transmit power using the Algorithm-VII for estimating the corresponding data to be allocated on subcarriers considering both primary and secondary users.
- *Algorithm-IX:* This algorithm performs greedy based approach to perform bit-loading operation targeting to minimize computational complexity.
- *Algorithm-X*: This algorithm is responsible for estimating the maximum level of bits to be allocated for each subcarrier.
- *Algorithm-XI*: This algorithm considers initializing the channel capacity of the subcarriers to its highest value and performs estimating the quantity of the subcarriers to be used. A deterministic function is written to accomplish the best throughput.
- *Algorithm-XII*: This is the last algorithm that focuses on formulating the optimal condition of the power allocation, bandwidth of the subcarriers. This algorithm finally computes the amount of the bits to be loaded.

The outcome of the study was found to be quite optimistic as it is mainly meant for static wireless network. Although, the authors have claimed that it may support mobility to some extent, but it is unlikely to support dynamic mobility pattern of the user in the wireless environment. Similar direction of the study was also carried out by Agarwal and Chaturvedi [44] the authors have used greedy approach for minimizing the power allocation of transmittance event in OFDM systems. The study outcome has shown minimal time complexity over OFDM system. Singh and Sood [45] have designed a system for optimizing the bit-loading performance under worst channel circumstances in OFDM. Similar study was also seen in [46].

The joint study on power as well as bit allocation exclusively for multiple carrier system was seen in work of Sun et al. [47].

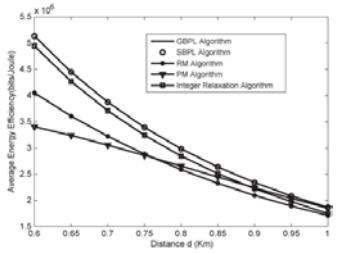

Fig.7. Outcome of work done by Sun et al. [47]

Authors have designed a system model for formulating the optimization problem in OFDM system under rate and error constraint. The outcome of the study is evaluated using iteration number and energy efficiency. The study outcome is shown in Fig.7, where it is found to possess 5 curves (e.g. curve-1 for GBPL algorithm for greedy based bit and power loading, curve-2 for SBPL algorithm for simplified based bit and power loading, curve-3 for RM (rate maximization) algorithm, curve-4 for PM (power maximization) algorithm, and curve-5 for work done by Gao et al. [48] approach for integer relaxation technique.

7 STUDIES

This section will discuss about the existing studies towards bit-loading and power allocation algorithm with respect to the specific networking systems in practice.

7.1 OFDM Network

It uses a multicarrier modulation technique, which is highly on demand in the present era. The traditional techniques of allocating resources in such system will require its parameters of physical layers to be fine tuned. It is normally done to enhance the user experiences over bad condition of channel. The existing research attempts essentially focuses on allocating the uniform bit rate on its multiple carriers which is highly adversely influence by various extrinsic parameters of channel. In the area of OFDM, the studies conducted on various factors are highlighted below,

- **Studies on Bit-Loading Algorithm**: Following are the researchers worked on bit-loading algorithms considering OFDM system viz. Jeney and Pap [16], Liu et al. [21], Vo et al. [23].
- **Studies on Power-Allocation Algorithm**: Following authors worked on power-allocation algorithms considering OFDM system viz. Han et al. [26]
- **Studies on Combined Algorithm:** Following are the researchers jointly worked on bit-loading as well as power-allocation algorithms considering OFDM system viz. Shen et al. [39], Agarwal [44], Singh [45], Wen et al. [46].

7.2 OFDMA

It is an extended version of OFDM; however, it differs from OFDM with respect to delay, avoidance of pulse carrier, minimal transmission power, ability to deal with narrow-band interference and channel fading. Before understanding resource allocation, it is essential to know that such systems are critically sensitive to noise and frequency offset. During maximum rate of data transmission, OFDMA system results in short burst in communication. Moreover, OFDMA system has complex subcarrier allocation system. The existing researchers attempted to perform bit-loading and power allocation approach with an aid of subcarriers, exhaustive search schemes, power levels, modulation and coding policies etc. Studies pertaining to massive transmission requirement, calls for using, enhancement in the cumulative throughput. Existing strategies switch over to this tradeoff between accomplished rate of error and anticipated bit rate by correcting the errors in link layer.

7.3 Power Line Communication

Such form of channel is used in transmission of data and is often characterized by echo, noise, frequency, interference etc. Hence, a typical pattern of technology is used in power line communication system. Literatures have also witnessed various techniques of DMT in power line communication system where CSI factor as well as SNR plays a very significant role. In the area of Power Line Communication, the studies conducted on

various factors are highlighted below

- **Studies on Bit-Loading Algorithm**: The study conducted by Morosi et al. [17] has emphasized on downstream link on power line communication system over DMT. Similar studies are also carried out by Costas Assimakopoulos and Pavlidou [18], Akujuobi and Shen [19].
- **Studies on Power-Allocation Algorithm**: Akujuobi and Shen [19] have worked on power-allocation algorithms considering power line system
- **Studies on Combined Algorithm**: Following are the researchers who have jointly worked on bit-loading as well as power-allocation algorithms considering Power Line System viz. Guerrini et al. [38], Wang et al. [41].

7.4 WLAN

WLAN is bascally compliant of IEEE 802.11 standards and uses multi-carrier modulation techniques increasingly. In the area of WLAN, the studies conducted on various factors are highlighted below

- **Studies on Bit-Loading Algorithm**: The study discussed by Wyglinski et al. [15] was aims to analyze the impact of SNR of subcarriers in WLAN.
- **Studies on Power-Allocation Algorithm**: Following are the researchers focused on power-allocation algorithms considering WLAN system Ahmed et al. [28], Dikmese et al. [30], Priya [49], Yao et al. [35].
- **Studies on Combined Algorithm**: Sudhir et al. [42],

7.5 Cognitive Radio Network

Adoption of cognitive radio network is increasingly seen in recent times. With respect to multicarrier-based communication, it has become a pivotal point of attention for implementing resource allocation algorithms. However, the concept of such implementation is quite new and majority of the work done till date is quite theoretical. The concept is associated with various problems with respect to interference for its primary users. In many cases, cognitive radio is studied in viewpoint of OFDM systems too. However, such system is associated with the problem of cyclic prefix that minimizes the cumulative capacity of the system. Very less work is done in this area.

8 Research Gap Identification

Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. Authors are strongly encouraged not to call out multiple figures or tables in the conclusion—these should be referenced in the body of the paper.

8.1 Inefficient Standardization

Till date the resource allocation algorithms were not seem to be studied discretely for wireless or wire line standards. As seen from prior section, we have categorized our findings for network specific study as OFDM, OFDMA, WLAN, cognitive radio, power line communication system etc. Majority of the implemented algorithms are more generalized, which creates a vagueness of its usage. Even if we choose to continue to investigate in this direction, we find that power line communication system and OFDM are the most active network chooses to study resource allocation. We also find that power line communication system was less studied with respect OFDM, almost none. In reality, OFDM technique could be also used in power line communication system for mitigating the adverse effect of multipath channels. Although OFDM supports high bit rate but it also has its flaws e.g. inadequate guard interval, frequency offset between receiver and transmitter, Doppler shift etc. Adoption of OFDM in power line communication will simply make the process of resource allocation more complicated in presence of such flaws. Unfortunately, such challenges still remain unexplored.

8.1 Vagueness in Algorithm Formation

We have studied that there are separate work being done either focusing on bit-loading algorithm development and implementation or only on power allocation algorithms. There are also certain works being done towards joint addressing of bit-loading and power allocation algorithm as a hybridized form. It is also evident that enough work is being carried out on OFDM owing to highest range of utilities provided by OFDM system in communication. However, when it comes to resource allocation, designing of bit-loading algorithms is developed to attain multiple objectives e.g. enhancing bit rate, adaption of code rate, power allocation, etc. A closer look into all the available techniques will shows that existing system of allocating power is non-optimal owing to bit discrimination technique adopted in all the combined study on bit-loading and power allocation in OFDM. This is one of the unseen problems that will result in performance degradation in OFDM system. The existing system exhibits that selection of length of cyclic prefix is almost equivalent to length of impulse response of particular channel. Unfortunately, such approaches make the system less efficient in terms of accomplishable throughput performance. Interference originated from carrier and symbol will be generated from shorter length of cyclic prefix. Some of the studies are found to dependent on CSI information too in many cases, but such approaches will result in loss of capacity. Hence, formation of an algorithm will require more attention on the case studies and micro-problems associated with it. Moreover attention is also required to perform parameterization. There is a need of more number of performance parameters to understand the actual outcomes.

8.2 Less Precision in Designing Wireless Multiuser OFDM System

The present paper has discussed many existing literatures and concluded that there is an increasing attention towards bit-loading and power allocation algorithms. Majority of the researchers claimed that such adoption will make the wireless system to ensure effective fairness, furnish optimal QoS, and also cater up the requirement of dynamic mobility environment. However, it is quite ob-

vious from the study that mobility is highly ignored performance parameters. By enhancing the utility function of the mean rate of user as well as incorporating the reduced constraints of data rate, it is feasible to control the fairness as well as QoS. It is also seen that studies are more focused on single user and less on multi-users. In such scheme, the researchers have evolved up with new strategies of time division multiplexing system. Some of the studies have also used deterministic channel links in case of arbitrary channel fading mitigation technique. Different authors have highlighted different scenarios, however none of them maps with the original scenario of wireless OFDM transmission considering channel fading on multi-users. Even in case of mobility, the simulation environment shouldn't have user node with uniform velocity. In fact, majority of the papers have not even considered the velocity attribute of mobility. Hence, in order to overcome such gap, it is critically essential that researchers should develop an analytical approach of power allocation as well as bit-loading technique right from the scratch for multiuser system.

8.3 Less Robust Greedy Approach

We have noticed that frequency of greedy approach is quite high in existing system for maximizing the bit rate and minimizing the power allocation. Usually, the greedy approach attempts to maximize the quantity of bits on certain subcarriers to it highest level based on cost function and subsequently extracts the condition of power to be allocated. What many researchers have not realized that designing of cost function for any specific cases of network is associated with higher dimensionality of communication problems that can easily generate a complicated scenario to execute cost using greedy approaches. Hence, it should be known that formulation of a condition to find the precise cost factor for enhanced greedy approach is a computationally complex process. This is because of the reason that when the quantity of the bit maximizes on a specific subcarriers, there is also a simultaneous need of altering the power levels of the subcarrier in presence of interference. There are few studies that have considered designing cost function using spectral mask as well as power constraints on OFDM networks. Hence, all the above points discussed are the identified research gap of literatures pertaining to existing bit-loading and power allocation algorithm. Moreover, majority of the existing studies are accompanied by specific limitations that are already highlighted in Table 1, Table 2, and Table 3. There is an emergence need of a mathematical model considering a standard scenario of wireless network and address the above stated research gap discussed in this section.

9 Conclusion & Future Work

In the present work, the area of bit-loading as well as power allocation techniques are reviewed under constraints of multicarrier communication system. However, we have also found that there are various types of wireless communication system e.g. OFDM, OFDMA, Cognitive radio network, WLAN, Power Line Communication etc. The paper has also discussed about the conditions for maximizing the data rate and minimizing the energy consumption under various rate and power constraints. The formulation of non-linear problems is also discussed in this paper. This paper has discussed about the essentials of bit-loading algorithm along with power allocation schemes in multicarrier modulated wireless system. The bit-loading algorithm is required to be highly enhanced in order to meet the target of next generation wireless standards. After reviewing the existing work, it can be only said that the research gap identified are quite critical and the noted points almost went unseen by the prior researchers

Our future work will be in the direction of mitigating such issues in bit-loading algorithms in future. In order to accomplish our goal, we have set following objectives for our future work e.g. i) designing a framework considering both carrier and symbol interference in OFDM system for the purpose of enhancing the system performance, ii) designing and developing an enhanced greedy based approach for further minimizing the system complexity and address the research gap pertaining to greedy approach, iii) designing a novel algorithm for bit-loading as well as power allocation in OFDM system considering the multicarrier mode of channel communication. We strongly believe that setting up such objectives will eventually overcome the research gap identified in this paper.

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