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Scheduling of OFDMA Networks at Relay Stations and Analyse QoS

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Abstract: For opportunistic network coding, let as present a novel model for network coding aware RSs. Here, an opportunistic network coding problem is reduced to an opportunistic sub channel scheduling problem. It is necessary to originate an optimization problem, which aims at maximizing the average weighted-sum rate for both downlink and uplink sessions of all MSs, while sustaining the quality-of-service (QoS) requirements of each MS. By solving it, an Adaptive Fuzzy resource scheduling algorithm that optimally and opportunistically schedule sub channel, transmission power, reduced power consumption, network coding, and time duration of each phase in each time-slot. To determine the resource share for flows attached to the same subscriber station (SS), a user-level proportional-loss scheduler is elected. The experimental results, shows how each of network coding strategy and dynamic TDD affects the network performance with various network environments.

Keywords: OFDMA, resource allocation, network coding, Time Division Duplexing, opportunistic scheduling, Adaptive Fuzzy algorithm, Quality of Service.

I. INTRODUCTION

Wireless communications is any measure, the fastest growing technique of communication industry, wireless operations permit services, such as long-range communications, that are impossible or impractical to implement with the use of wires. Wireless communication networks are expected to provide high data-rate coverage in the most cost-effective manner [1]. To achieve this, high-spectral-efficiency schemes are required in conjunction with aggressive resource reuse strategies to ensure prudent use of scarce radio resources [2]. Interest in orthogonal frequency-division multiplexing (OFDM) is growing steadily, as it appears to be promising air- interfaces for the next generation of wireless systems due to its inherent resistance to frequency selective and multi path fading and the flexibility it offers in radio resource allocations. In future wireless systems, each user will expect a high throughput so they can access different multimedia services regardless of their location and mobility.

Network coding refers to a method in which each node may send a single coded data with combining several data to be forwarded. Here, the transmitted data is encoded and decoded to increase network throughput [1]. In wireless networks, especially in wireless ad-hoc networks, network coding is used significantly to improve network performance by using an appropriate network coding scheme which exploits the broadcasting nature of the wireless medium [9]. Network coding provided a novel IP and MAC layer protocol for ad-hoc networks, COPE, which uses XOR network coding [1]. XOR network coding can improve network throughput by reducing the number of transmissions as well as by reducing hot spots in wireless networks. In the OFDMA system, each subchannel can be allocated to a different transmission allowing flexible network coding for each subchannel.

Network coding is impossible for opportunistic resource scheduling at relay nodes at which two-hop data are encoded and multi-casted to destination nodes. Hence, they focused on maximizing the instantaneous throughput taking snapshot approaches without considering scheduling at relay nodes. In a two-hop transmission, the effective data rate of the two-hop transmission is limited by the link with a lower capacity among two wireless links from/to the relay node in a timeslot. When one of those wireless links experiences bad channel conditions, it cannot fully exploit the other wireless link with good channel conditions [3]. It can alleviate this problem by allowing relay nodes to opportunistically adjust scheduling and transmissions rate. Specifically, when an RS performs network coding to exchange data between BS and MS, such opportunistic scheduling at RS plays more important roles.

This paper provides an opportunistic resource scheduling algorithm for the relay-based OFDMA cellular

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network with network coding at RSs with downlink and uplink sessions of an MS, downlink session include transmission from RS to MS and uplink session include transmission from MS to RS which includes joint subchannel and transmission power scheduling, network coding strategy, and time duration adjustment for each phase. The RSs are stationary whereas the MSs are mobile. Assume that network coding can be performed opportunistically at RSs, i.e, whether or not to perform network coding and which sessions will be encoded together at each RS are determined considering time-varying channel states of wireless links.

Opportunistic network coding, introduce a novel model for network coding aware RSs with which opportunistic network coding strategy decision can be reduced to opportunistic subchannel scheduling. To support two-hop transmissions of network coded data, consider a time-division duplexing (TDD) based time-slot structure, it consists of N orthogonal subchannels and each channel is divided into time slots. Where a time-slot consists of three phases: the first, second, and third phases are allocated for the transmissions of the BS, MSs, and RSs, respectively. The main aim to formulate an optimization problem is to maximize the average weighted sum-rate for both downlink and uplink sessions of all MSs, inorder to satisfy the Quality of Service (QoS) requirements like throughput, power consumption of each MS. By solving the optimization problem, this proposed method develops an adaptive fuzzy resource scheduling algorithm that fully exploits opportunistic network coding.

In the forth coming section, system model is presented in section II. Section III, formulates an optimization problem and develop an opportunistic resource scheduling algorithm that solves the resource allocation problem. Simulation results and discussions are presented in section IV, and conclusion is followed in section V.

II. System Model

A. Network Architecture, Time-slot Structure, and Channel Model

Let as consider a single cell OFDMA network with one Base Station, *M MSs*, and *N* Relay Stations, as depicted in Fig. 1. The BS is located at the centre of the cell and RSs are located around the BS. The sets of RSs and MSs are denoted as *N* and *M*, respectively. Assume that each MS has its own downlink and uplink sessions and all RSs operate in a decode-and-forward and half duplexing mode.

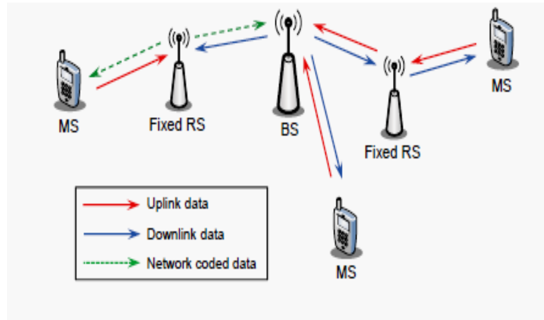

Fig 1 A relay-based OFDMA cellular network

Consider a Time Division Duplexing system in which each time-slot is further divided into three phases in time according to the transmitting nodes such as MS, BS, and RS in each phase, as in Fig. 2

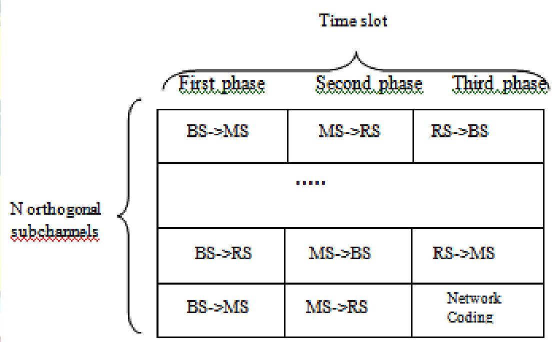

Fig 2 A time-slot structure for the relay-based OFDMA cellular network

At the first phase, only the BS can transmit data to MSs and RSs and at the second phase, only MSs can transmit data to the BS and RSs. At the third phase, RSs can forward received downlink data from the BS to MSs and received uplink data from MSs to the BS.

In OFDMA network the whole frequency band is divided into N orthogonal sub channels each of which consists of a number of subsequent subcarriers. The subcarriers are orthogonal to each other. Consider the channel state of a wireless link to be time-varying and frequency-selective. The channel state is flat within a subchannel and unchanged during a timeslot. The channel state of each wireless link on each subchannel as a stationary stochastic process. In addition, a system state can be defined as the combination of the current channel state of all wireless links on all sub channels in the system. Since our assumption is that the channel state is stationary, the system state also can be modelled as a stationary stochastic process,

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and thus in each time-slot, the system is in one of possible system states with the same probabilistic properties.

Let as consider the opportunistic resource scheduling at RSs as well as BS and MSs. At every RS the data received from the BS or MSs stored within the buffers present in the RSs and the resource scheduling and the network coding strategy can be adjusted in accordance with the current channel states of its outgoing wireless links. In order to improve the efficiency of opportunistic resource scheduling which allow that the duration of each phase can be adjusted dynamically according to the time varying channel states of wireless links.

B. Model for Network Coding-Aware System

Let as assume that the RSs are able to perform network coding. The BS and all MSs store the data that are already transmitted to RSs for two hop communications within their own buffers for some time. RS perform network coding with downlink and uplink sessions of an MS. The MS and the BS can decode the received coded data to retrieve their data. In the network coding aware system, the coded data can be forwarded to multiple nodes in a single transmission.

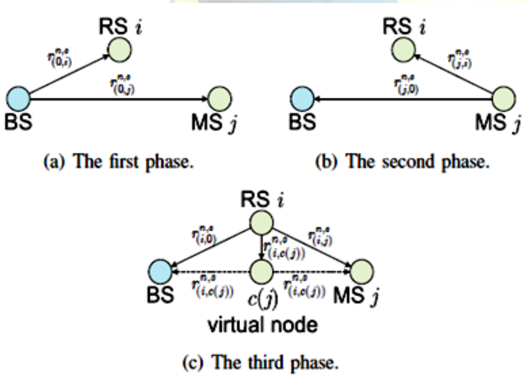

Fig. 3 The achievable data rate of each wireless link for each phase

In order to effectively model such multicast transmissions of the coded data and simplify the mathematical presentations, let as introduce a virtual node for each MS as in fig 3. Let as denote the virtual node of MS j as c(j) in eqn (1) and (2) and define the set of virtual nodes, C,as

$$C=\{c(j) \mid j \in M\}. \quad (1)$$

A virtual link between each RS and each virtual node, which can be used only for coded data transmissions from RSs at the third phase, and the set of virtual links is defined as

$$V=\{(i, c(j)) \mid i \in K, j \in M\} \quad (2)$$

In the third phase the XOR network coded data with the downlink and uplink sessions of MS j is multicast to both MS j from i through that subchannel. The coded data can be transmitted to both the BS and the MS from the RS. For successful decoding of coded data its transmission data rate should be smaller than or equal to the minimum between the achievable data rates.

III. Opportunistic Resource Scheduling

Opportunistic resource scheduling aims to maximize the average weighted sum-rate of downlink and uplink sessions of all Mobile Stations. Opportunistic resource scheduling can be provided by Fuzzy algorithm. The stochastic optimization problem can be formulated as

$$\max_{q,p,f} \sum_{s \in S} \pi_s \sum_{i \in K \cup \{0\}} \sum_{j \in M} (w_j^{DL} R^s_{(i,j)} + w_j^{UL} R^s_{(j,i)})$$

$$\sum_{s \in S} \pi_s \bar{f}_s(\bar{q}_s, \bar{p}_s) = 0$$

$$\sum_{s \in S} \pi_s \bar{g}_s(\bar{q}_s, \bar{p}_s) \geq \bar{0} \quad (3)$$

Hence, the equality in eqn (3) represents the constraints on two-hop transmissions defined, the inequality represents the constraints for the QoS requirements of each MS defined, and the inequality represents the restrictions on the average transmission power of each node defined.

A. *Stochastic Sub-gradient Algorithm*

The sub-gradient method is a simple algorithm for minimizing a non differentiable convex function. The method is similar to ordinary gradient method for differentiable functions, but with several notable exceptions. Let as consider an example that the sub-gradient method uses step lengths that are fixed ahead of time, instead of an exact or approximate line search as in the gradient method. Unlike the ordinary gradient method, the sub-gradient method is not a descent method; the function value can increase. The sub-gradient method is far slower than Newton's method, but is much simpler and can be applied to a far wider variety of problems. By combining the sub-gradient method with primal or dual decomposition techniques, it is sometimes possible to develop a simple distributed algorithm for a problem.

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By Danskin's Theorem, the stochastic sub-gradient of F($\bar{\delta}$) at the k-th time-slot with $\bar{\delta} = \bar{\delta}^{(k)}$ is obtained as $[\bar{x}^{(k)}, \bar{y}^{(k)}, \bar{z}^{(k)}]$, as in eqn (5) where

$$\bar{x}^{(k)} = \bar{f}_s(k)\left(\bar{q}_s(k)(\bar{\delta}^{(k)}), \bar{p}_s(k)(\bar{\delta}^{(k)})\right),$$

$$\bar{y}^{(k)} = \bar{g}_s(k)\left(\bar{q}_s(k)(\bar{\delta}^{(k)}), \bar{p}_s(k)(\bar{\delta}^{(k)})\right),$$

$$\bar{z}^{(k)} = \bar{h}_s(k)\left(\bar{q}_s(k)(\bar{\delta}^{(k)}), \bar{p}_s(k)(\bar{\delta}^{(k)})\right), \quad (4)$$

In the sub-gradient algorithm for each subchannel BS allocates subchannels and transmission power based on channel states and Lagrangian multipliers.BS adjust the portion of phase duration based on the achievable aggregate data rate in each phases. BS updates Lagrangian multipliers based on instantaneous data rates and transmission power.

B. Fuzzy Mechanism

In earlier methods Sub-gradient scheduling can be provided where the power consumption can be increased as the number of nodes increases, Hence Fuzzy Mechanism can be used. Fuzzy logic is a form of many valued logic or probabilistic logic, which deals with reasoning that is approximate rather than fixed and exact. Fuzzy logic variables may have true values that range between 0 and 1. Fuzzy statements are statements containing names of fuzzy sets. It has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. Fuzzy logic operates in non differentiable, non linear equations. In this method all the nodes arriving at different time can be examined continuously so that worst case condition can be avoided in this proposed method. This method is a simple method for minimizing non differentiable convex function.

Mamdani's method is the most commonly used in applications, due to its simple structure of 'min-max' operations. Mamdani inference system uses the following steps:

1. determining a set of fuzzy rules
2. fuzzifying the inputs using the input membership functions,
3. combining the fuzzified inputs according to the fuzzy rules to establish a rule strength,
4. finding the consequence of the rule by combining the rule strength and the output membership function,
5. combining the consequences to get an output distribution, and
6. defuzzifying the output distribution (this step is only if a crisp output (class) is needed).

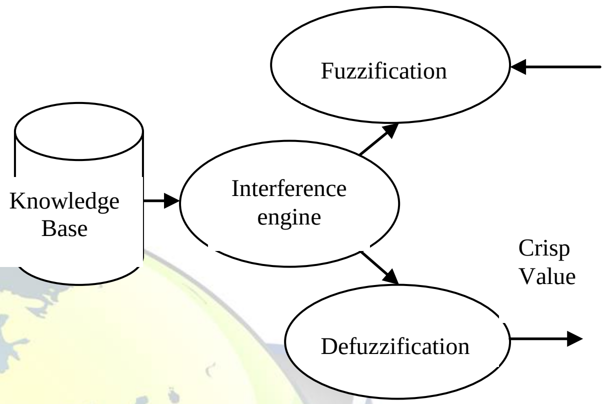

Fig. 4 Structure of a fuzzy inference system

- **Fuzzification module:** transforms the system inputs, which are the crisp numbers, into fuzzy sets. This is done by applying a fuzzification function.
- **Knowledge base:** stores set of rules provided by experts.
- **Inference engine:** simulates the human reasoning process by making fuzzy inference on the inputs and provide rules.
- **Defuzzification module:** transforms the fuzzy set obtained by the inference engine into the crisp value.

IV. Results And Discussion

This paper illustrates the simulation results for the proposed resource scheduling algorithm. For the simulation fist consider a single cell of an OFDMA based cellular network with 10 heterogeneous nodes uniformly distributed around the BS. The heterogeneous nodes are places at a distance between 20 to 120 cell radius and the total frequency bandwidth W=10MHz and the AWGN noise power No=-174dBm/Hz. Time-varying frequency selective wireless channels are modelled considering path loss, shadow fading, and fast Rayleigh fading where the channel state of each subchannel is assumed to vary independently with each other.

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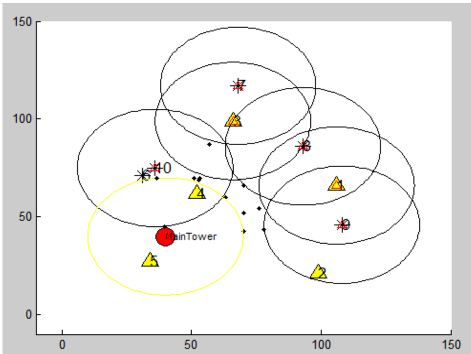

Fig. 5 Assigning heterogeneous nodes around BS

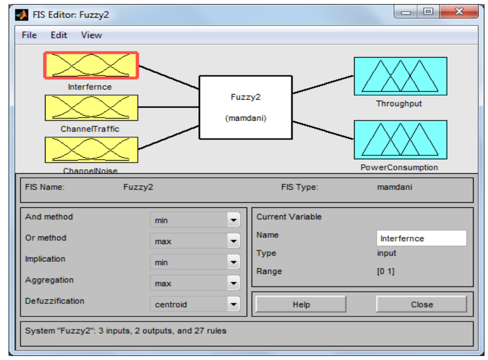

Fig. 7 Fuzzy Input

The BS if found at one place and 10 heterogeneous nodes are distributed uniformly around the BS as in Fig 5. The nodes are placed between 20 to 120 cell radius The main tower is denoted by red circle and signal transmission is given by yellow circle where as the heterogeneous nodes are indicated by yellow delta and star and corresponding signal transmission is represented by blue circles. First the heterogeneous nodes send request to the main tower for data transfer and the main tower sends the acknowledgement to the heterogeneous nodes to identify its acceptance.

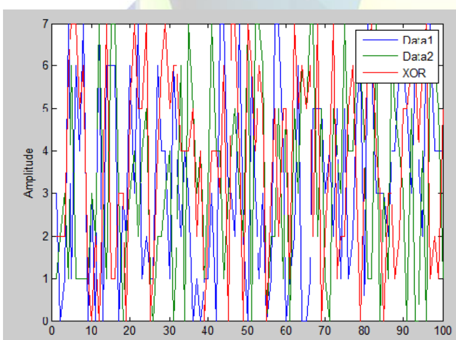

Fig. 6 XOR network coded data

Consider two data sequence represented by blue and green colour as in Fig 6 they undergo PSK modulation and the modulated data sequence are XORed to give the network coded data indicated by red colour. The two data sequence are XOR network coded to minimize the delay and noise present in the data sequence to improve the performance thus the resulting XOR data sequence is free from noise which is given for the calculation of power consumption.

In case of Fuzzy Mechanism Interference, Channel Traffic and Channel Noise acts as the input crisp values to the system and by applying the Mamdani rule the output crisp values obtained are throughput and power consumption as in Fig 7. The Fuzzy technique is an online resource allocation method. At defuzzification centroid value can be calculated. By applying Mamdani rule scheduling can be done continuously in online mode.

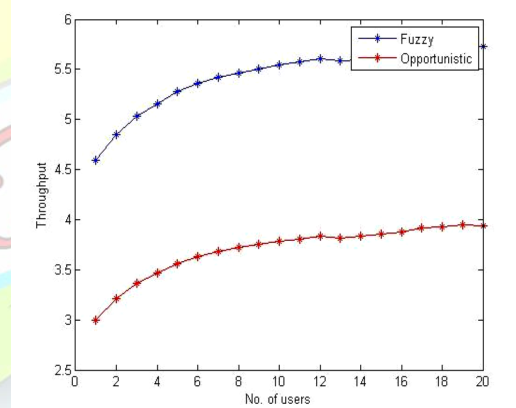

Fig. 8 Throughput Vs Number of Users

Network throughput is the average rate of successful message delivery over communication channel. Let as consider 20 users and for them the average rate of message successfully delivered can be calculated. The throughput obtained by this method is better when compared to the throughput obtained for 20 users by the existing methods such as sub-gradient, graph base subchannel and power allocation algorithm.

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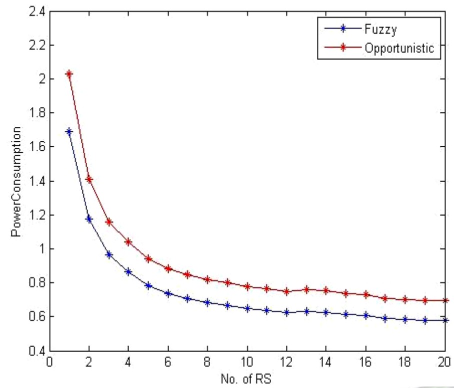

Fig. 9 Power Consumption Vs Number of RSs

The opportunistic scheduling algorithm aims to minimize the power consumption at every node at each time slot. Fig 9 shows that the power consumed by this method is very much reduced by Fuzzy mechanism for 20 users than the earlier sub-gradient method.

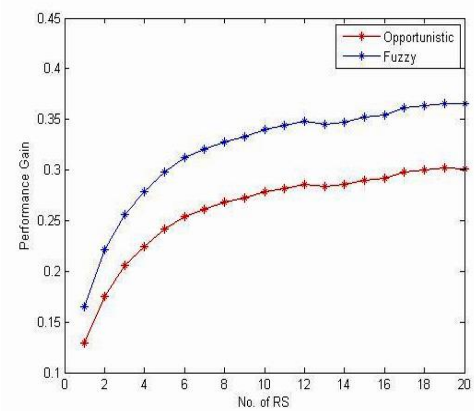

Fig. 10 Performance Gain Vs Number of RSs

Performance of an OFDMA network can be analyzed by its gain. If the gain is high then the performance of the network is better. Performance gain can be given by Throughput/Power consumption. Fig 10 shows that the performance gain of the network using Fuzzy mechanism for 20 users is high compared to opportunistic scheduling algorithm.

Thus Fuzzy Mechanism results in increased throughput, reduced power consumption and high gain and thus satisfies the Quality of Service requirements, hence resource scheduling in OFDMA networks with Fuzzy Online technique is better when compared to opportunistic resource scheduling algorithm.

V. Conclusion

This paper provides an opportunistic resource scheduling problem in the relay based OFDMA network with opportunistic network coding at RSs. Through solving the optimization problem for this system, results in the development of a Fuzzy algorithm that can fully utilize the technique such as network coding and dynamic TDD with considering the time varying channel states. Here the opportunistic scheduling algorithm converges to the optimal scheduling, while satisfying the constraints on the QoS requirements. The performance of the opportunistic scheduling algorithm improves the network throughput with less noise and reduce the amount of power consumed by each node. This proposed Fuzzy Scheduling algorithm provides substantial performance improvement compared with the other algorithms that cannot allow consider network coding and/or dynamic TDD.

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