Advance Co-Existence System of Long Term Evolution Relevances

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Abstract: Due to the increasing demand for higher data rates and the congestion in communication systems, new research is focusing on the cooperation between the two most successful communication systems, LTE and WiFi. The overall performance of a WiFi system degrades with increasing the number of served users due to collisions. We propose in this paper a novel scheme for LTE and WiFi coexistence, where an LTE femto Base Station cooperates with a WiFi Access Point to maximize both of their profits. Our proposed scheme has the advantage of relieving a congested WiFi system. Thus, this creates a time gap for the LTE system to transmit its data. In addition, we investigate the capability of WiFi and LTE systems to work simultaneously under a certain maximum interference limit. We have formulated a multi-objective optimization problem for maximizing the rate of the WiFi system and the capacity of the LTE system. We developed an algorithm based on particle swarm optimization to determine the appropriate time ratios for WiFi and LTE transmission, the transmitting power of LTE under WiFi transmission, and the number of WiFi nodes to be transferred to LTE system. Simulation results confirm the capability for LTE to transmit besides WiFi without affecting its transmission rate.

Keywords*:* Amplify-And-Forward Relay, Channel Estimation, MIMO-OFDM, Spatial Fading Correlation, Training Design, Twoway Relay.

I. INTRODUCTION

With the proliferation of technology and mobility, there is a tremendously increasing demand on mobile telecommunications and its support for higher data rates. The demand on mobile telecommunications is expected to increase by 1000 times by 2020 [1]. LTE is the most promising technology that is spectrum efficient, that enables development and enhance-ment. However, the mobile spectrum will be unable to cope with the increasing demand for higher transmission rates. Currently, there is a drift toward utilizing LTE in the unlicensed bands. Qualcomm [2], Nokia [3] and many others have discussed the opportunities for LTE in the unlicensed bands and how it can utilize the unlicensed bands. WiFi systems are intended for distributed management. That is, each station takes the decision of transmission independent from other stations. However, in LTE, the decision is made by the Base Station (BS), which is responsible for the distribution of resource blocks among its stations (nodes). Therefore, LTE system uses the channel more efficiently than WiFi. This was confirmed by a field trial conducted by Lan et. al. in [4]. The results also clarify the importance of handling interference effect on WiFi transmission. In this paper, we propose a novel scheme for the operation of LTE in the unlicensed band. The basic idea here is to maintain the WiFi transmission rate unaffected by the operation of LTE. This is done through relieving the WiFi system with the aid of LTE system, by moving some of the WiFi nodes to be served by the LTE system. Relieving the WiFi system will allow for some resources to be used by the LTE system (win-win situation). We formulate a multi-objective optimization problem to maximize the WiFi rate and the LTE capacity; we optimize the number of WiFi nodes to be served by the LTE system, the transmission power and the time allocation between WiFi and LTE systems. Then, we use the Particle Swarm Optimization (PSO) technique to derive the Pareto curve and choose an optimum point that keeps WiFi transmission rate unaffected.

II. RELATED WORK

There exist a lot of research efforts toward the existence of LTE in the unlicensed bands without affecting the existing systems that use bands. Some research work examines ways to mitigate interference effect on small networks such as WiFi. Other work proposes new schemes for coordination between LTE and other networks. Frameworks for coordination between LTE and WiFi sys-tems are proposed by Sagari et. al. in [5] and Liu et. al. in[6]. An enhancement on [6] is presented in [7], where two models are proposed: either Dual-Band Femtocell, where LTE works on both licensed and unlicensed bands, or Integrated Femto WiFi, where LTE system acts as a WiFi system in the unlicensed bands. In addition, it presents a scheme for channel access and a framework for dynamic spectrum management. Some research is targeted toward treating the coexistence as a competition and models it using game theory such as [8] and [9]. Some other research proposes fairness-based schemes for the coexistence such as [10] and [11]. Bennis et. al. propose a game theoretic model for offloading delay-tolerant data traffic from Small-Cell Base Stations (SCBSs) to WiFi in[8]. In addition, they present a machine learning framework for self-organized SCBSs using reinforcement learning and cross learning. On the other hand, a proportional fairness scheme is presented in [10], where an optimization problem for maximizing the capacity given a certain number of WiFistations and LTE stations is proposed. In [11], Salem and Maaref propose an algorithm for user equipment centric joint association and channel selection. Abdel-Rahman et. al. make use in [12] of doubling the spectrum efficiency through full-duplex WiFi transmission. In [13], Ratasuk et. al. discuss three different scenarios, either a single operator at multiple 20 MHz channels, a single operator at a single 20 MHz channel, or multiple operators at the same 20 MHz channel. In [14], Jeon et. al. mathematically analyze the effect of interference on the quality of service of both LTE and WiFi stations. Attar et. al. discuss in [15] radio resource management schemes, such as selfish schemes using Listen Before Talk (LBT) or collaborative schemes. However, the most relevant work to ours would be that in [16].

Chen et. al. present a model for relieving WiFi system through moving some WiFi stations to the LTE system. Though, conversely, they do not study the advantage of allow-ing simultaneous transmission of both WiFi and LTE systems, which we consider in this paper. Our model is more general as we optimize the time allocated for simultaneous transmission of the WiFi and LTE stations; if the optimum allocated time for simultaneous transmission is zero, our system reduces to the one in [16]. As stated above, there is barely a little work in the field of merging underlay coexistence with time division coexistence, in other words, to have the opportunity for LTE to transmit while WiFi is transmitting, and also to have a dedicated time slot for LTE transmission. Most contributions that present a model for simultaneous transmission of LTE and WiFi systems do not investigate the benefits of cooperative coexistence of both systems.

III. SYSTEM MODEL

Our system model consists of an LTE femto Base Station (fBS) which serves LTE nodes and a WiFi Access Point (AP) which serves WiFi nodes. The assumption of one fBS and one AP is adopted to simplify modeling and analysis of the system. Nevertheless, the model can be readily extended to add a number of WiFi APs and/or a number of LTE fBSs. However, it requires modeling of the fairness of each AP and fBS and also modeling for how these diversely connected systems organize and schedule their transmissions. Nowadays, most of the electronic devices support LTE and WiFi transmission. Therefore, we depend on this in our model. However, compared to [16], we assume that there are some WiFi nodes that support WiFi transmission only and their number is n_w. The rest of WiFi nodes support LTE transmission and their number is = $n_l = N_w - n_l$. We assume that the Signal to Interference and Noise Ratio (SINR) between a transmitting node and a receiving node , subject to an interference from node , is equal to

$$SINR_{AB/C} = \Gamma_{AB/C} = \frac{h_{AB} P_A}{h_{CB} P_C + \sigma_n^2} \qquad (1)$$

where σ_n^2 is the noise variance, Pa and Pc are the transmitted powers from nodes A and C, respectively, and $h_{AB}$and h_{CB} .

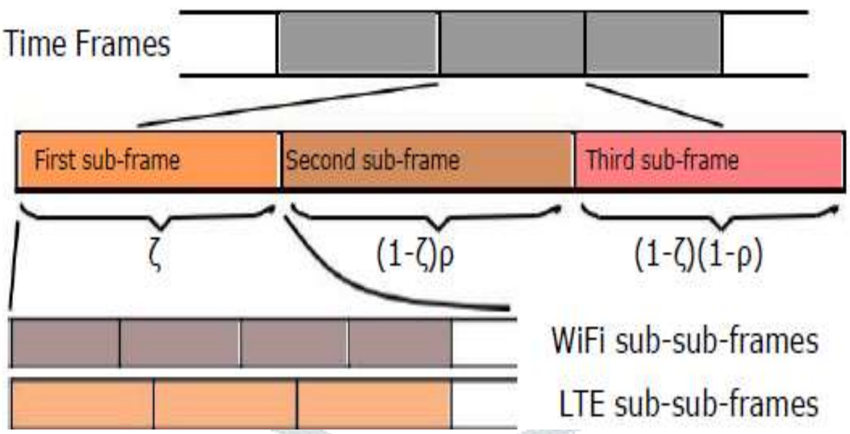

Fig.1. Explanation of Time Division between WiFi and LTE system.

represent the channel strength between nodes A to B and B to C, respectively. We assume that $h_{AB} = C_o d_{AB}^{-\gamma}$, where C_o represents the path loss constant and γ is the path loss exponent. For simplification, we assume that the channel is constant over the transmission time. However, the model can be extended to include these variations. The fBS should sense the existence of nearby APs and identify their attached nodes and their capabilities to communicate through LTE. However, this assumption is not prac-tical. Therefore, we suggest that there will be a neutral or governmental authority that coordinates and monitors WiFi activity and LTE requirements. This coordinator is capable of managing the spectrum and distribute resources to achieve a better overall performance for both systems; also, it is responsible for maintaining synchronization between them. The coordinator will typically divide the channel into time frames with each consisting of three different sub-frames. Each sub-frame contains several LTE and WiFi sub-sub-frames. Therefore, Each system will operate normally and independently from the other one except at the transitions between sub-frames, which the coordinator is responsible for when to occur. The structure of the time division is depicted in Fig.1 and can be described as follows.

First Sub-Frame: WiFi and LTE transmit simultaneously. The LTE system will transmit with a certain power so that the interference on the most vulnerable WiFi node will not exceed its interference limit. If the transmission of LTE will have an effect on WiFi nodes, then the highest priority will be given for WiFi to transmit.

Second Sub-Frame: LTE helps the WiFi system by handling the transmission of some of its nodes. Thus, the WiFi system is relieved and a higher rate can be achieved. The WiFi system is idle in this sub-frame.

Third Sub-Frame: LTE transmits the data of its nodes. The LTE system will have full control of the channel to transmit the data of its nodes without having to be cautious about the interference from or to the WiFi system. The reason is that the WiFi system is idle in this time sub-frame.

Finally, we assume that WiFi nodes, which support LTE(1) transmission and have the strongest channel to the fBS, have the highest priority to be assigned to the fBS, if needed. This is to have the least interference effect on WiFi transmission and to have the highest channel gain between the fBS and its attached WiFi nodes. In the subsequent subsections, we will discuss the modeling of the data rate for both LTE and WiFi.

IV. IMPLEMENTATION

The optimization problem is too difficult to be solved using the Karush Kuhn Tucker (KKT) conditions. In addition, the Hessian matrix of is not negative semi-definite to guarantee its concavity. Hence, we use a meta-heuristic technique to solve it. More specifically, we use the Particle Swarm Optimization (PSO) technique to generate the Pareto-optimal curve of our two objectives for different values of the distances between the LTE fBS and the WiFi AP. Then, we choose a point on the Pareto-optimal curve that maximizes LTE capacity constrained by the conservation of the capacity of the WiFi system as shown in Algorithm 1.

Algorithm 1 Multi-Objective PSO Algorithm

Input: Data in Tables I and II

Output: C_{LTE}, C_{WiFi}, τ, ρ, n and I

for each separation value between AP & fBS **do**
  for each generation of nodes (N_{dis}) **do**
    Generate $Population$, satisfying (7.3), (7.4), (7.5) & (7.6) and calculate C_{LTE} & C_{WiFi}.
    Calculate objectives for each particle, Obj_l and Obj_w
    Check domination of $Particles$ and define $Leaders$.
    Create $Grid$ and Place $Leaders$ in it.
    for $iteration = 1$ to N_{it} **do**
      for Each Particle **do**
        Select a suitable $Leader$ of a $Cell$ in the $Grid$.
        Calculate $Particle$'s $Velocity$ and $Position$.
        Check $Constraints$ Violation and calculate C_{LTE}, C_{WiFi}, Obj_l & Obj_w.
        Apply $Mutation$ and check if $Position$ is better than $Best$. If better, replace.
      end for
      Update $Leaders$, $Grid$ & w_{new}
      Check if $Leaders$ size $> N_{lead}$, remove extra.
    end for
    Choose the optimum $Particle$
  end for
  Calculate averages of C_{LTE} and C_{WiFi}
end for
return P

The values of Obj_l and Obj_w are as follows,

$$Obj_l = C_{LTE} - penalty * (< dif_1 > + < dif_2 >) \quad (2)$$

$$Obj_w = C_{WiFi} - penalty * (< dif_1 > + < dif_2 >) \quad (3)$$

Therefore, to guarantee the satisfaction of those two remaining constraints, we subtract a penalty value from our two objectives; the LTE and WiFi transmission rates. The penalty is linearly proportional to how much a particle diverges from satisfying each of the two constraints as in (8) and (9). In case a particle satisfies all constraints, the penalty would be equal to zero.

V. SIMULATION RESULTS

Simulation results of this paper is as shown in bellow Figs.2 to 13.

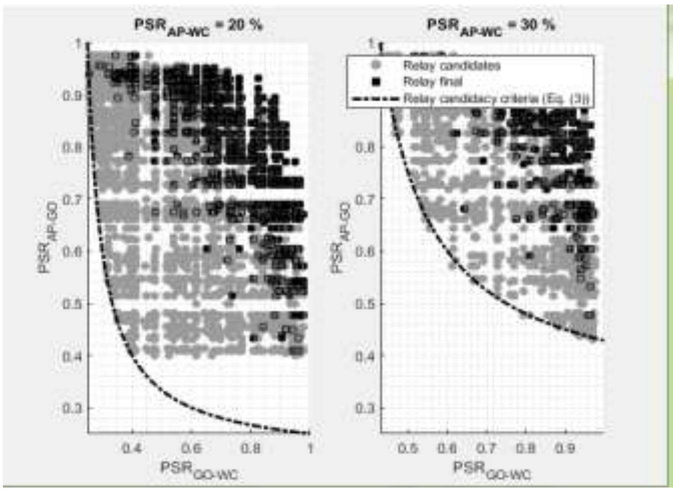

Fig.2. Feasible region.

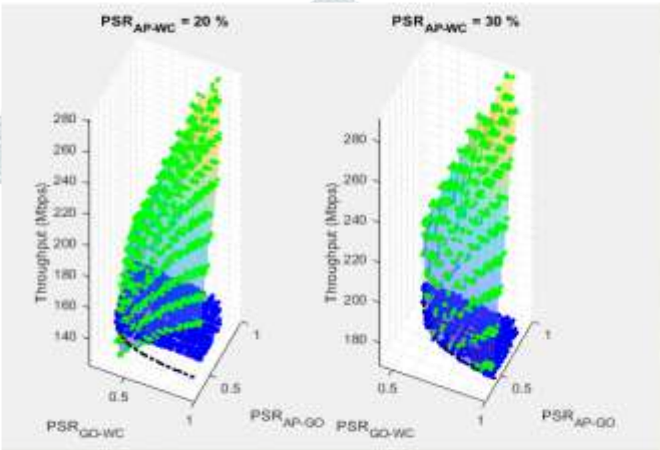

Fig.3. Feasible region.

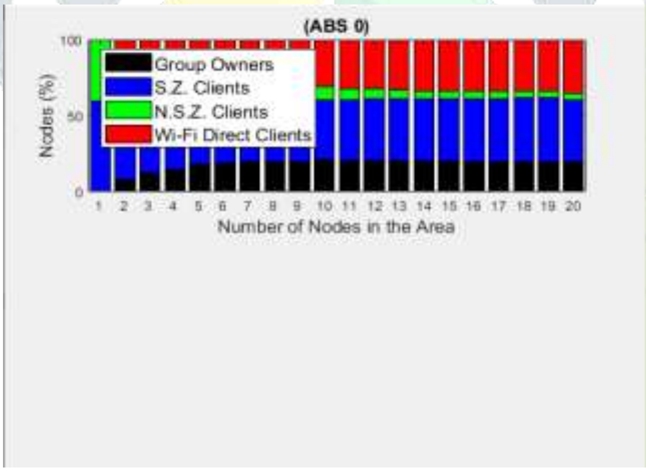

Fig.4. General stats plot 1.

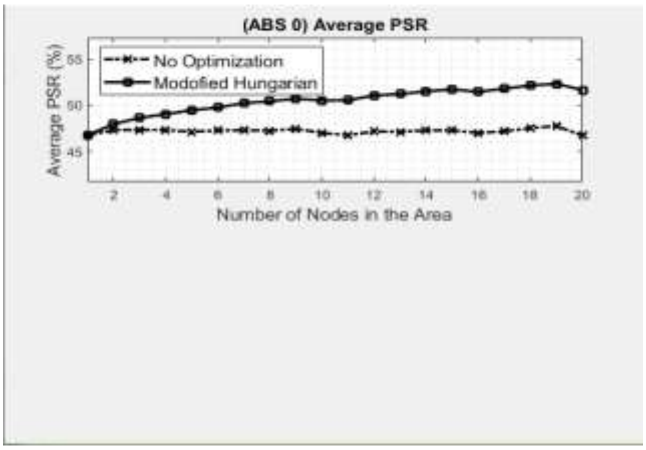

Fig.5. General stats plot 2.

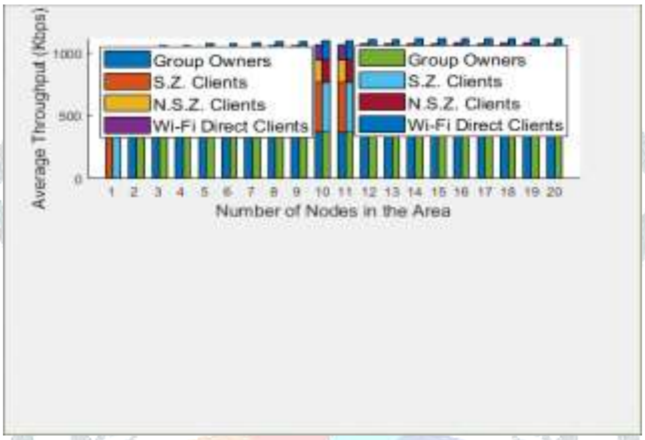

Fig.6. General stats plot 3.

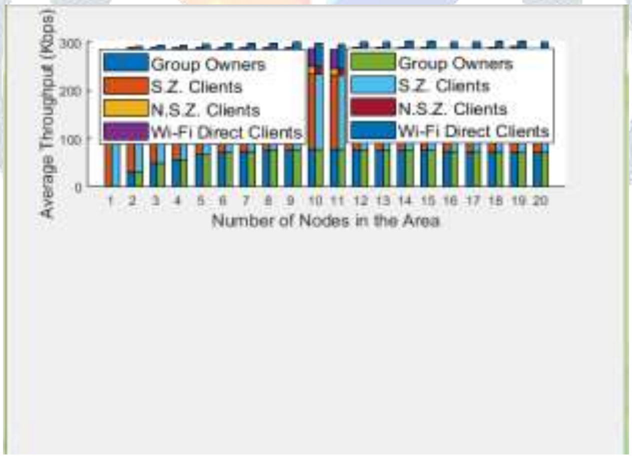

Fig.7. General stats plot 4.

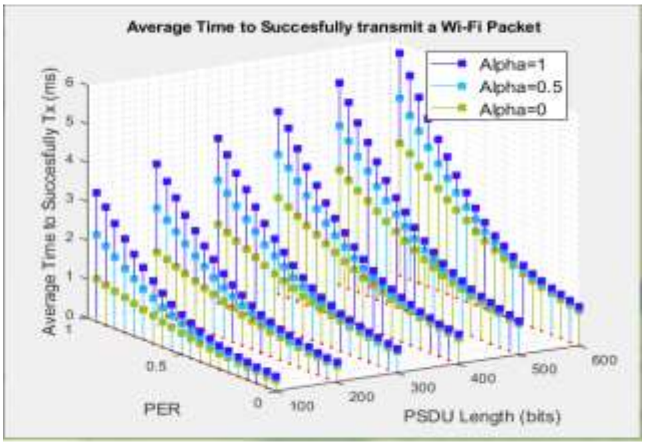

Fig.8. Table plot 1.

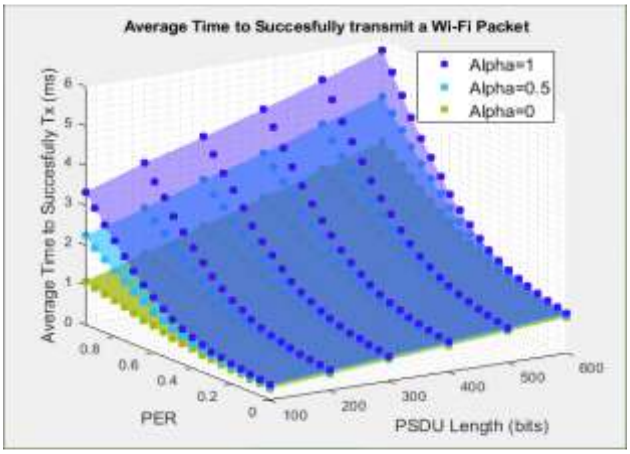

Fig.9. Table plot 2.

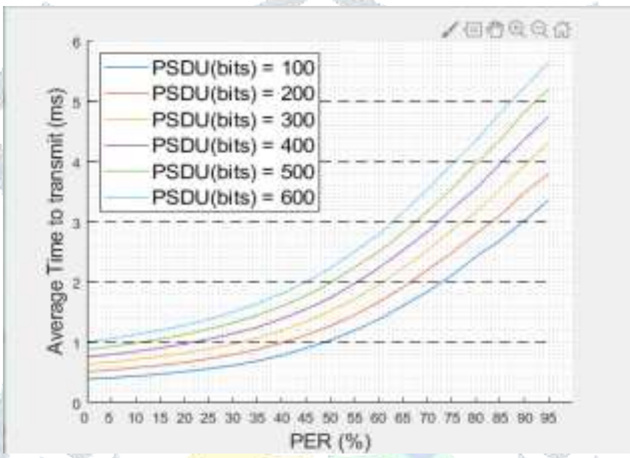

Fig.10. Throughput 1.

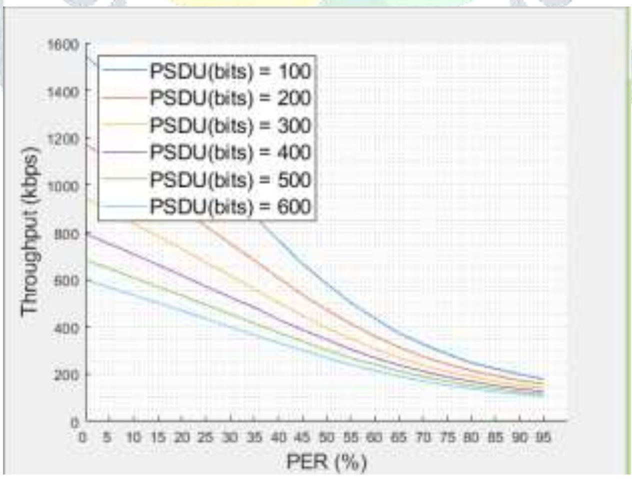

Fig.11. Throughput 2.

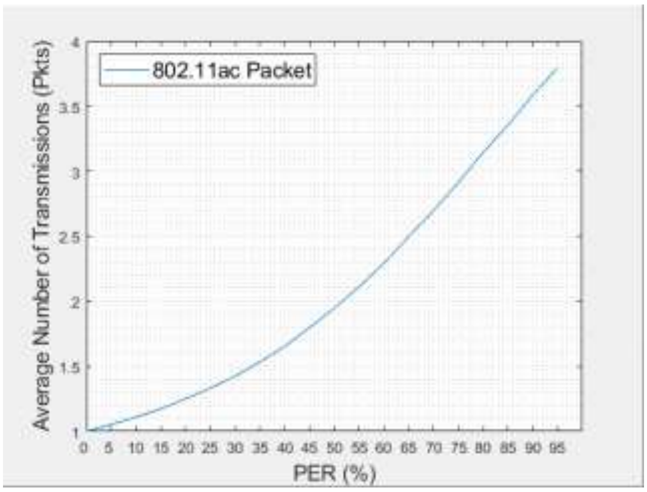

Fig.12. Throughput 3.

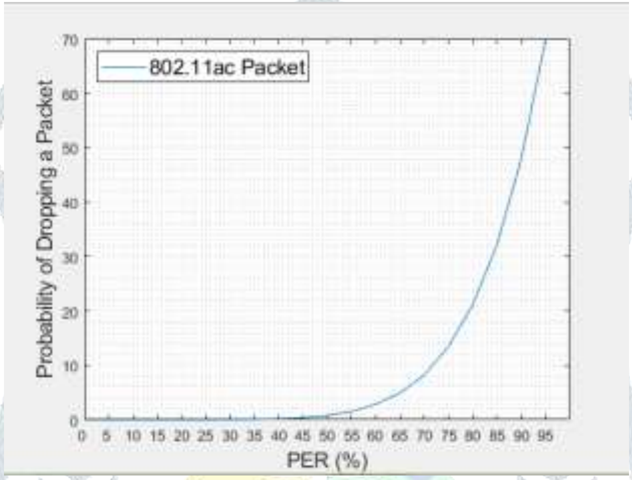

Fig.13. Throughput 4.

VI. CONCLUSION

In this paper, we have discussed the capability of LTE to operate, coherently and effectively, with a nearby WiFi system in the unlicensed band. The LTE system relieves the WiFi system and, thus, gets a dedicated time for its transmission. We have modeled the problem as a two-objectives optimization problem. PSO was used for solving the problem and producing the trade-off curve between LTE and WiFi transmission rates. An appropriate point on the curve can be chosen that guarantees the WiFi rate. Simulation results indicated the effectiveness of the proposed cooperative coexistence scheme. The proposed scheme outperforms a previously proposed scheme where the time is divided between the WiFi and LTE systems, by allowing simultaneous transmission of the two systems.

VII. REFERENCES

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