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Novel Energy Efficient & Optimized Downlink Traffic Scheduling Schemes in LTE-A with Dual Connectivity Enhancement

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Abstract

With the increase in traffic demands, the infrastructures needed to be developed. Small cell implementation in LTE-A resolves the problem of serving the traffic with high load and unpredictability. Thus, networks with one macro(MeNB) and several slave (SeNB) have been deployed. The capacity of these networks can be enhanced if we use the dual connectivity of a User Equipment with the both SeNB and MeNB. Since, energy efficiency is always demanded to increase in condition, if data traffic increases too much and overall energy consumption increases too much.

Thus, we need to increase the overall network through put and improve energy efficiency for better network realization.

Simulation results show that DTS algorithm solves the problem of scheduling and enhances the overall network throughput. Proper offline analysis and offloading load can increase the enrgy efficiency of the system.

Keywords: DTS, eNB, LTE-A, network throughput, energy efficiency, optimization

INTRODUCTION

Network infrastructure using LTE-A is able to meet the demand of increasing high-sspeed data services. It’s the technology well capable to meet the demand of increasing network capacity and offloading the traffic.

To fulfill diverse QoS requirements is more challenging in wireless networks as compared to the wired networks. This is due to the limited radio resources, the time-varying channel conditions and resource contention among multiple users. Packet scheduling deals with radio resource allocation and is directly related to the QoS provision to users demanding different services. Three classic packet scheduling algorithms are Round Robin (RR), Maximum Carrier to Interference (MAX C/I) and Proportional Fairness (PF).

These algorithms consider system-level performance such as fairness and system spectral efficiency, and do not consider the QoS requirements of different services from individual users. The current state of the art packet scheduling algorithms mainly take QoS provision into consideration in order to provide better service experience for each individual user. However, the performance of QoS aware packet scheduling algorithms at both user-level and system-level has not been addressed properly. Direct Traffic Scheduling takes care of the network throughput and QoS provisions. It includes the advanced optimization techniques for the traffic scheduling for the best network throughput.

There have been lot of researches done to increase the energy efficiency of the overall system. Thus, improving the overall power consumption efficiency and meeting the demands of the high data throughput and ensuring QoS delivery.

Our focus is to minimize the total network power consumption by offloading traffic to small cells to reduce the overall power consumption of the network, and assumptions made on the user

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traffic profile and behaviour. This involves reducing the active operation time of both the radio access network (RAN), as well as the backhaul network. Dual connectivity feature enables macro cells to route traffic through small cells in real-time, depending traffic flow, essentially increasing the time during which small. Thus, overall power consumption can be reduced using this strategy.

In the downlink traffic scheduling(DTS) scheme, the MeNB periodically executes the proposed DTS scheme to arrange the data rate of downlink traffic splitting to SeNBs for UEs that have dual connectivity for an upcoming interval. While scheduling downlink data, the MeNB first imports the collected up-to-date system and network parameters to the designed hybrid mixed integer linear programming (MILP) – Constraint Programming problem, whose objective is to maximize the network throughput.

The combined hybrid optimization algorithm is able to solve the critical constraint problems as well as feasibility of that solution as well. CP improves the overall optimization to reach overall optimum solution where the constraints for the MILP is very tightly constrained. CP methods use effective constraint propagation algorithms for scheduling that are based on the ideas of edge finding and task intervals. There are complementary strengths of the MILP and the CP methods that may possibly be combined to tackle more difficult problems. The advantage of the MILP model is that the values of the assignment. variables obtained from the LP relaxations direct the branch and bound search to obtain the least cost assignments.

It also follows the algorithms for mitigation of interference that takes care of SINR and packet delivery ratio and ensures QoS.

ENERGY EFFICIENCT NETWORK SCHEME

In this section, we study the reduction of the overall energy consumption due to the offloading decision. In the dual connectivity environment considered, we assume that the offloading takes place only when the MeNB estimates that the action reduces the total energy of the network, or if the QoS of the traffic flow can be improved, thereby utilizing the SeNBs efficiently.

The overall energy consumption of the network can be reduced by an offloading action, decision taken on the basis that the MeNB power consumption is lesser than that with SeNB.

The QoE can be improved by identifying the traffic flows towards an UE (using techniques such as deep packet inspection at the eNB or using QoS parameters of the bearer, and determine whether possible additional energy consumption due to the offloading action would lead to better network utilization.

In a dual connectivity environment, the cell activation criteria would depend on the energy saving criteria as well as the QoS constraints defined by the network operator. Thus, the MeNB can offload traffic to SeNB either when the ES criteria is satisfied, or when based on the traffic flow analysis, the offloading action would provide better QoE to the end user, thereby justifying the additional energy consumption in the network.

The value indicates the probability of the traffic of a UE not satisfying the energy saving criteria, being offloaded to the SeNB, thereby improving its QoE. In a real system, this would indicate the traffic flow type of the UE, and whether offloading the traffic would lead to a noticeable increase of QoS for the UE.

The expression is as below:

$$\Delta_{P(macro)}\,\rho_{o(macro)}\,P_{m(macro)} > \Delta_{P(pico)}\,\rho_{o(pico)}\,P_{m(pico)} + P_{bh\_st(pico)}$$

Where $\rho_{o(macro)}$, $\rho_{o(pico)}$ are the offloaded data traffic towards macro and pico (SeNB) cells. $P_{bh\_st}(pico)$ indicates the static backhaul power consumption increase dueto activation of the pico cell, and its corresponding backhaull ink.

Following the study done in [12], for a system

with N_A antennas, P_0 the power consumption at zero RF output power, Δ_p the slope of the load dependent power consumption, P_m [W] is the maximum RMS transmit power of the base station, ρ_k is its corresponding load, and P_s the power consumption [W] when the BS is in sleep mode, the Total power consumed by the BS cell k, P_{Ck} [W] is given by:

$$P_{Ck} = \begin{cases} N_A (P_0 + \Delta_P \rho_k P_m) + P_{bh}, & \textit{Active state} \\ N_A P_S & \textit{Sleep State} \end{cases}$$

$$\rho_k = N_{Uk} / N_T$$

Here we consider a system where each BS has a finite amount of resources and the load of the system depends on N_U, the number of resources being used out of a total N_T available resources. For cell k having a total of N_T resources, using N_{Uk} resources, the load is given by ρ_k .

For calculatingthe throughput on the serving link as well as potential targetcell, we considered the effective bandwidth model used in [8],[13].

The capacity of the link S [b/s/Hz] is:

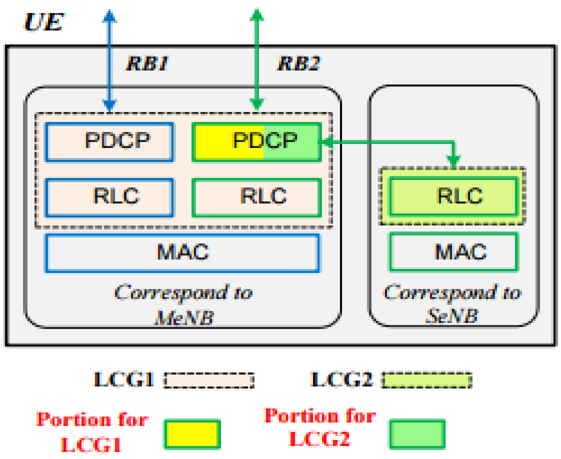
$$S = \min\left(B_{eff} \,.\, \log2\,(1 + SINR/SINR_{eff}),\, S_{eff} \right)$$

$$N_U = R/(S.RB_S)$$

$$C_{cellk} = \sum_{i=1}^{N_{UE}} R_i$$

TRAFFIC SCHEDULING METHODOLGY

1. The eNB uses the Channel Quality Indicator (CQI) information for the allocation decisions and fills up a RB "allocation mask". The eNodeB uses both CA and MIMO features to take a scheduling decision based on QoS parameters and buffer status.
2. The AMC module selects the best MCS that should be used for the data transmission by scheduled users
3. The information about these users, the allocated RBs and the selected MCS are sent to the UEs on the Physical Downlink Control Channel (PDCCH)
4. Each UE reads the PDCCH payload and, in case it has been scheduled, accesses to the proper Physical Downlink shared Channel (PDSCH) payload.
5. Each UE decodes the reference signals, computes the CQI, and sends it back to the eNB



OPTIMIZATION SCHEDULING IN LTE-A NETWORKS

MILP problems can be solved using Linear Programming (LP)-based Branch & Bound (B&B) solvers or with stochastic search based solvers. The advantage of the first approach is that it provides rigorous lower and upper bounds on the solution, which in turn provide information regarding the optimality of the solution

(MILP):

$$Z(X) = \min\{cx + fy : (x, y) \in X\}$$

where,

$$X = \{(x, y) \in \Re + \times \{0,1\}^{p} : Ax + By \geq b\}$$

c ,f, b are constants, A and B are matrices of constant. B&B Algorithm relies on the start of the linear relaxation of form

$$X = \{(x, y) \in \Re + \times \{0,1\}^{p} : Ax + By \geq b\}$$

(CP):

$$\min \sum_{i \in I} C_{iz}$$

s.t

$$i.start \geq r_i$$

$$i.start \leq d_i - p_i$$

$$i.duration = p_{zi}$$

where z is the resource block selected amongst the all RB i.

DTS ALGORITHM

Based on the architecture, for those UEs that have dual connectivity, the MeNB needs to decide how many downlink data that those UEs can receive from the connected SeNBs. While scheduling, if the MeNB arbitrarily transfers UEs' downlink data to SeNBs, the SeNBs may not be able to deliver these data to UEs because of poor channel quality.

Conversely, if UEs can receive only some downlink data from SeNBs, the benefit of deploying SeNBs is limited (because the MeNB handles most downlink data). As discussed in the 3GPP standard [4] and many 3GPP documents, scheduling the downlink traffic for UEs that have dual connectivity is challenging because many system and network parameters

(e.g., buffer status, channel quality, application data rate, and backhaul capacity) must be considered while making the scheduling decision.

However, these schemes cannot be applied to the target scenario because of the following two reasons. First, these schemes only focus on scheduling downlink traffic for UEs that are located in an eNB. Second, these schemes do not consider how the MeNB splits data flows to SeNBs for UEs that have dual connectivity. Recently, several traffic scheduling solutions for LTE-A small cell networks with dual connectivity are proposed. In [2], a fixed traffic splitting method is discussed, i.e., the MeNB and SeNBs handle x% and $(100-x)$% of packets, respectively. In [1], the MeNB decides how many packets can be relayed to an SeNB according to the SeNB's radio capacity and the backhaul latency. In [11], an SeNB periodically requests data from the MeNB according to its buffer status and radio capability.

We can observe that these schemes [1][2][11] consider only some system and network parameters while scheduling. More importantly, these schemes cannot facilitate fully utilizing the benefit of deploying small cells because they do not attempt to maximize the network throughput while scheduling.

The MeNB periodically executes the proposed DTS scheme every It = k × TTI ms, where k is a system parameter. Subsequently, for each bearer bj ∈ Bc, the MeNB can obtain rsp(bj), which represents the data rate of bj that will be split to the corresponding SeNB during the upcoming I t interval. (Note that rsp(bj) ≤ γ(bj) and rsp(bj) = 0 if bj ∈ {Bm ∪ Bs}.) At a schedule time t, the MeNB executes the DTS scheme through the following four steps:

1) For each ui ∈ {Uc ∪Us}, the MeNB gathers Ds(ui) and ui's CQI reports on SeNB MU→S(ui)

2) For each u i ∈U, the MeNB first calculates the average CQI report value of ui on the MeNB and SeNB MU→S(ui) during the (t − It, t) interval. The MeNB then uses the AMC algorithm and the ui's average CQI values to obtain Om(ui) and Os(ui), which represent the estimated amount of data that can be carried by ui's RB transmitted via the MeNB and SeNB MU→S(ui), respectively.

3) The MeNB solves the MILP & CP problem to obtain rsp(bj), ∀bj ∈Bc.

4) During the upcoming (t, t + It) interval, for each bearer bj ∈Bc, the MeNB continually splits and dispatches downlink data to the corresponding SeNB, i.e., MU→S(MB→U(bj)), according to the decided rsp(bj). Then, at time t+It, the MeNB resets the schedule time t = t + It and goes back to step 1.

RESULTS &DISCUSSION

Table 1. Simulation Parameters

Parameters	Values
Carrier Frequency	2/3.5 GHz
System bandwidth	10MHz
Transmission Power	50dBm
Scheudling Algorithm	DTS
Antenna Configuration	MIMO
Multiplexing type	OFDM (FDM)
Path Loss Model	128.1 + 37.6log(d)

The simulation is done by using optimized DTS scheme by MATLAB simulation. Here, it's assumed that the UEs have dual enhanced connectivity in them. As the UEs are mobile and can be present anywhere between the SeNB and MeNBs. The simulation is done for the above stated scheduling of data traffic by various means.

Here, MeNB represents the macro cell and SeNB represents the slave cells or the micro cell (pico cell). Thus, the data traffic percentage in MeNB(0) is zero UEs handles by the Macro cells. Similarly MeNB(50) represents the 50% of the data traffic handled by the MeNB and so on.

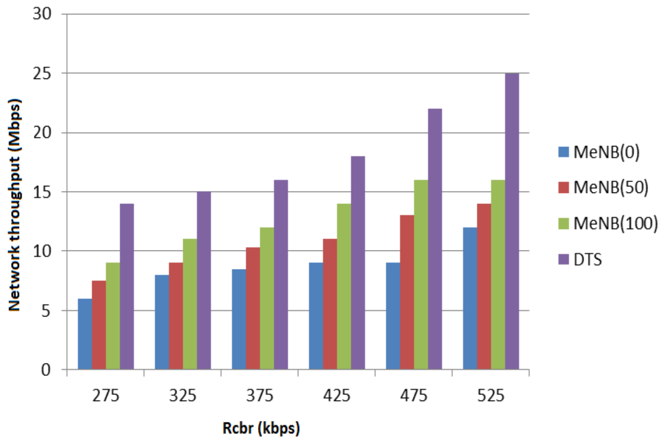


Figure 3. Network throughput vs Rcbr

Here, simulation is done by assuming the bearer type as constant bit type(CBR). Fig .3 represents the network throughput analysis with the increase in the Rcbr.

Results shows that the optimized DTS is found to follow the most throughput rather than other scenarios. Thus, the result verifies that the DTS is optimized for maximum throughput rather than the other scheduling scenarios.

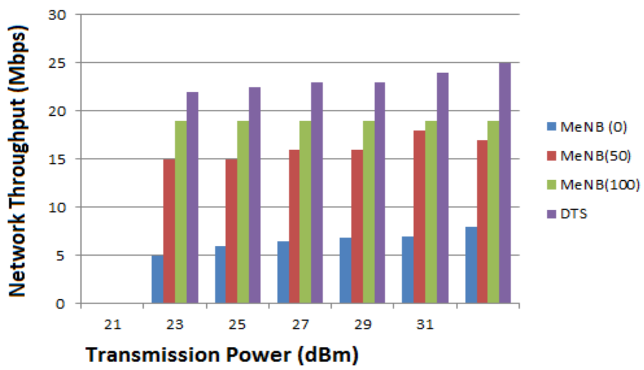


Figure 4. Network throughput vs Transmission Power

Fig .4 represents the network throughput analysis with the increase in transmission power. It shows the power efficiency.

Results shows that the optimized DTS is found to follow the most throughput rather than other scenarios for increasing power. Thus, the result verifies that the DTS is optimized for maximum throughput rather than the other scheduling scenarios.

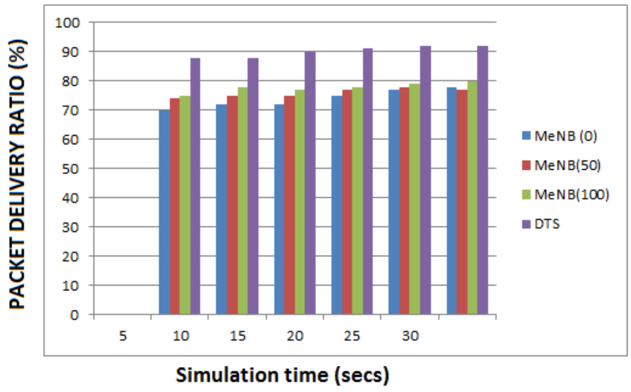


Figure 5. Packet Delivery ratio vs Simulation time

Fig .5shows the Packet delivery ratio analysis between the scenarios.

Results shows that the optimized DTS is found to follow the higher Packet delivery ratio rather than other scenarios for increasing power. Thus, the result verifies that the DTS is optimized for maximum PDR rather than the other scheduling scenarios.

CONCLUSION

The results compare the scenario where the scheduling has been done with and without DTS. We have analyzed the consequences of the DTS in the overall performance of the dual connectivity based traffic scheduling.

We have compared the network throughput and Packet delivery ratio as quality parameter for the scheduling. As proposed, the MILP algorithm along with CP algorithm provides the better optimization to fulfill the constraints related to the QoS like CQI, transmitted power, fair index etc.

Thus, with the simulated results, we have shown that the throughput has been increased and the power requirement has been lesser in demand and thus increasing the overall packet delivery ratio.

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