An Improving Strategy for LTE Downlink Scheduling Algorithms Based on QoS Requirement

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Introduction

- LTE adopts the concept of a resource block (RB), which is typically a number of consecutive subcarriers in the frequency domain and the time domain
- A RB formed by the intersection of a sub-channel in frequency domain and a slot in time domain is the smallest allocable resource unit
- The main issue to be addressed is how RBs are allocated to users, given that the channel conditions for each user are different

Introduction

- Resource allocation for each UE is usually based on the comparison of per-RB metrics: the k th RB is allocated to the j th user if its metric $m_{j,k}$ is the biggest one among all users, i.e., if it satisfies the equation:

$$m_{j,k} = \max_{i} m_{i,k}$$

- Even with the help of multiuser diversity, the traditional algorithms cannot maintain the QoS of users in poor channel conditions when the total resources are shortage

The intuition of our work

- Multi-user scheduling is in charge of distributing available resources among active users in order to satisfy their QoS needs. This goal should be accomplished by providing a trade-off between spectral efficiency and fairness
- The idea of PF is that the past average throughput can act as a weighting factor of the expected data rate.
- Because PF can get a good trade-off between spectral efficiency and fairness. Most of exist scheduling algorithms are based on it.

The intuition of our work

- But in our opinion, when a user get a max metric under PF or the improved version of PF at one time. The resource have not to be allocated to the user. Because the user may get a higher transmission rate later. And this resource can be saved and allocated to the user with poor channel.
- For example, let's see an instance with only a channel.

time	t1	……	t2
user1	900/600	……	1500/1400
user2	500/600		300/1400

The intuition of our work

- All of the scheduling algorithms above take QoS, throughput and fairness into account, although different in the method of tradeoff.
- For the users in bad channel conditions, even the multi user diversity gain cannot always help to maintain the QoS.
- We start from the scheduling problem of a single user. Then we design a strategy of improvement for these scheduling algorithms, aiming to satisfy the QoS of more users

The Models

- Model 1

$$\min \sum_{r=1}^{M} \sum_{i=1}^{T} x_{ri}$$

$$s.t. \sum_{r=1}^{M} \sum_{i=t_{start}^{j}}^{i=t_{end}^{j}} R_{ri} x_{ri} \geq Th_{Datasize}^{j}, \quad j \in J \, and \, t_{start}^{j} \leq t_{end}^{j}$$

$$x_{ri} \in \{0, 1\}$$

$$x_{ri} = \begin{cases} 1, & \text{the } r\text{th RB at TTI i is allocated,} \\ 0, & \text{else.} \end{cases}$$

The Models

- Model 2

$$\min \sum_{r=1}^{M} \sum_{i=1}^{T} x_{ri}$$

$$s.t. \sum_{r=1}^{M} \sum_{i=(u-1)\Delta t+1}^{(v-1)\Delta t+Th_{dealy}} R_{ri} x_{ri} \geq \sum_{k=u}^{v} P_k,$$

$$x_{ri} \in \{0, 1\}$$

The Models

- Model 3 (The model similar to the set cover model)

$$\min \sum_{k=1}^{MT} x_k$$

$$s.t. \quad \sum_{k=1}^{M(t^j_{end}-t^j_{start})} R_k x_k \geq Th^j_{Datasize},\ j \in J\ and\ t^j_{start} \leq t^j_{end}$$

$$x_k \in \{0,1\}$$

- In this model, suppose the minimal granularity of data is 1 bit, that is, the values of all the data, including the transmission rate of every RB and the size of every data packet, are integers. It is very similar to the problem of weighted set cover.
- The only difference is that some RB may not be available to transmit some data until a certain TTI.

The Algorithms

- greedy algorithm

```
U ← ∅;
V ← D_all;
while V ≠ ∅ do
    j ← argmax RR_j;
    U ← U ⋃ {j};
    trans(j) ← the first RR_j elements of cov(j) ⋂ V
    V ← V \ trans(j);
    Update V and all RR_i if i is not in U;
end
return U;
```

Algorithm 1: greedy algorithm

The Algorithms

- Modified greedy algorithm

✓ The basic idea of Algorithm 2 is to conduct the scheduling from 0 to T many rounds. In each round, select the RBs whose actual data transmission quantities are not less than TH_{trans}.

✓ Initially, TH_{trans} is set to be the maximum transmitting speed of all the RBs. Each round TH_{trans} reduces by 1 until THtrans = 0 or all the data packets have already been transmitted. After the selection of a RB, we update the size of each packet

The Algorithms

- Modifyed greedy algorithm

Because the actual transmission quantity of a RB selected by Algorithm 2 each round is required to be larger than some threshold value, it equals to the biggest probable transmission rate. So the results obtained by Algorithm 2 is the same as the results obtained by Algorithm 1.

```
U ← ∅;
TH_trans ← max_{t,r}(R_{t,r});
while TH_trans > 0 and max_k(P_k) > 0 do
    n ← 1;
    h ← 1;
    for t ← 0 to n do
        if t = G_{t_n} then
            n ← n + 1;
        end
        if t = G_{t_h} + D_{T_h} then
            h ← h + 1;
        end
        for r ← 1 to M do
            if min{R_{t,r}, Σ_{k=h}^{n} P_k} ≥ TH_trans then
                j ← t * M + r;
                U ← U ⋃ j;
                k ← h;
            end
            while k ≤ n and R_{t,r} > 0 do
                RR ← min {R_{t,r}, P_k};
                P_k ← P_k − RR;
                R_{t,r} ← R_{t,r} − RR;
                k ← k + 1;
            end
        end
    end
    TH_trans ← TH_trans − 1;
end
return U;
```

Algorithm 2: modified greedy algorithm

Improving Strategy for LTE Downlink Traffic Scheduling

- As in Algorithm 2, we can see that if a user only selects the RBs with the transmission quantity RRj near the maximal transmission quantity in a recent period, the number of total RBs allocated to this user will be restricted.
- As the channel conditions are usually expected to be changing continuously, the transmitting rate R for some user is very likely to appear again in a short time, say, ΔT.

Improving Strategy for LTE Downlink Traffic Scheduling

- Sometimes, the user is moving, so the channel conditions will get worse. If the transmitting rate has been far away from the peak value $maxR_j$ for a time ΔT, we can say the channel condition of this user is changing and update the maximal transmitting rate $maxR_j$ according to the records in the recent ΔT.

Improving Strategy for LTE Downlink Traffic Scheduling

The basic idea of the Improving Strategy is:

- For the users under better channel conditions, the scheduling algorithm will only allocate the RBGs with the rate near the peak rate to them, restricting the number of used RBGs.
- For the users under worse channel conditions, the scheduling algorithm should be able to allocate more RBGs to them

Improving Strategy for LTE Downlink Traffic Scheduling

- For any user j, record the maximal transmission rate $maxR_j$ in a recent period with length ΔT
- For some RB k in some TTI, if the actual transmission rate $RR_{j,k}$ is near $maxR_j$, the metric of the transmission priority should be near the index in the primal algorithm.
- Otherwise, if $RR_{j,k}$ is much less than $maxR_j$, the index should be reduced. The strength of reduction depends on the actual demand.

$$M_{jk} = m_{jk}\left(\frac{RR_j}{\max R_j}\right)^{\beta_j}$$

Improving Strategy for LTE Downlink Traffic Scheduling

The improving strategy

In this paper, the β_j is set that $\beta_j = \exp(c(mpls-pls_j))$, where pls_j is the packet loss rate of user j in a recent period and mpls denotes the maximal packet loss rate over all users at this TTI.

```
for j ← 1 to N do
    flag ← false;
    for r ← 1 to M do
        if R_{j,r} ≥ max_R_j then
            flag ← true;
        end
        max_R_j ← max{max_R_j, R_{j,r}};
        temp_max_R_j ← max {temp_max_R_j, R_{j,r}};
        Calculate the index m_{jr} in the primal scheduling
        algorithm;
        RR_j ← min {R_{j,r}, the accumulated data in the
        queue of user j at this TTI };
        calculate β_j;
        M_{jr} = m_{jr}(RR_j / max_R_j)^{β_j};
    end
    if flag then
        temp_max_R_j ← 0;
        t_j ← 0;
    end
    else
        t_j ← t_j + 1;
    end
    if t_j = ΔT then
        max_R_j ← temp_max_R_j;
        temp_max_R_j ← 0;
        t_j ← 0;
    end
end
```

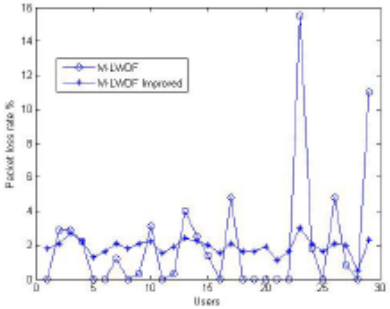
Algorithm 3: improving strategy

Simulations

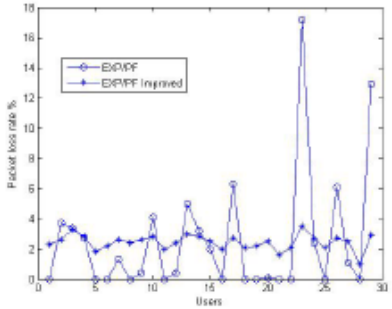
To prove the efficiency of our strategy, we compare the results of both the primal and improved versions of M-LWDF, EXP/PF algorithms in three different cases.

- 1 channel, 29 users in the service of VoIP;
- 1 channel, 23 users in the service of HD voice;
- 13 channels, 23 users in the service of video conference.

Simulation Result

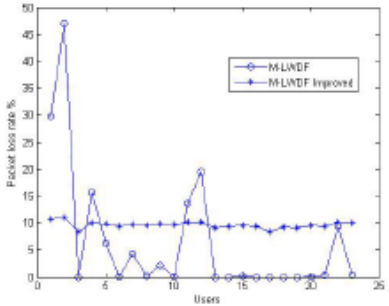


(a) M-LWDF

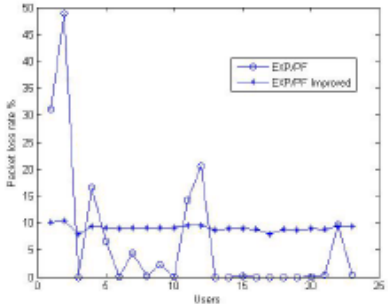


(b) EXP/PF

Fig. 1: packet loss rates in case 1

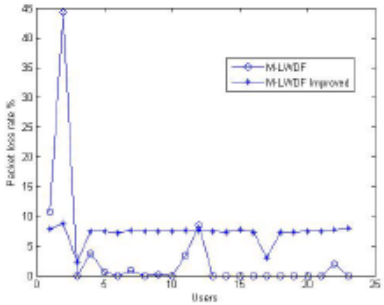


(a) M-LWDF

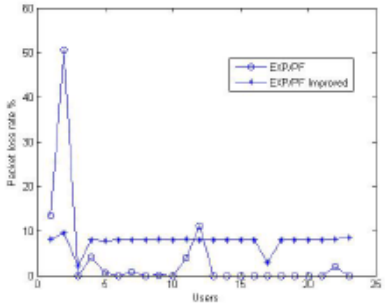


(b) EXP/PF

Fig. 2: packet loss rates in case 2



(a) M-LWDF



(b) EXP/PF

Fig. 3: packet loss rates in case 3

Thanks !