Cooperative Communication for Content Distribution in Downlink Cellular Network

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Abstract
As more and more data-driven applications are emerging, the demand for data rate are also increasing exponentially specially in the cellular network. Sometimes the Quality-of-service (QoS) are not guaranteed for all user equipments (UEs). To meet this demand, massive MIMO, LTE-A, cooperative communications are considered as the suitable candidate for the next generation cellular network. As most of the smart phones have multiple connectivity, we consider cooperative communication among UEs as a possible solution of this problem in our paper. We use matching theory to find suitable candidates to cooperate in the network. Simulation results are shown to represent the performance of the process.

1. Introduction

The number of smart devices like smartphone are gaining popularity due to its more powerful multi-functional capabilities and a report [1] predicts that 70% public of the universe will carry a smartphoe by the end of 2020. These smart devices are creating the demand of more data haul applications. A recent study [2] found that mobile subscribers produced 3.7 exabytes of data traffic worldwide per month in 2015 and the amount will reach 30.6 exabytes per month by 2020. The study [1] also prognosticates that 80% of mobile data traffic will generate from smartphones and online video will be the source of 60% of mobile traffic till 2020. The mobile users download the multimedia-rich contents directly from the base station in current cellular network, which leads to huge traffic congestion to networks in the upcoming days.

The network can achieve performance many times when both transmitter and receiver employ multiple antennas. However, the cost and complexity of massive MIMO implementation in BS is a tenacious job in current situation. But the performance of such network can be enhanced significantly with the increase number of receiving antennas[3]. At present, smartphones and tabs are equipped with multiple network connectivity. So, a natural way to handle the traffic congestion labyrinth is to employ multiple connectivity of the receiving devices by means of cooperation. There are many proposal of cooperative communication in cellular network. In [4], the authors propose a cooperative D2D transmission framework in cellular network. The authors propose superposition coding-based cooperative relaying process to grab the transmission opportunity of D2D without affecting the performance of cellular users in [5].

In this paper, we propose a cooperation mechanism among UEs based on matching game in cellular network. We have showed the results of the proposed method in simulation and performance evaluation section.

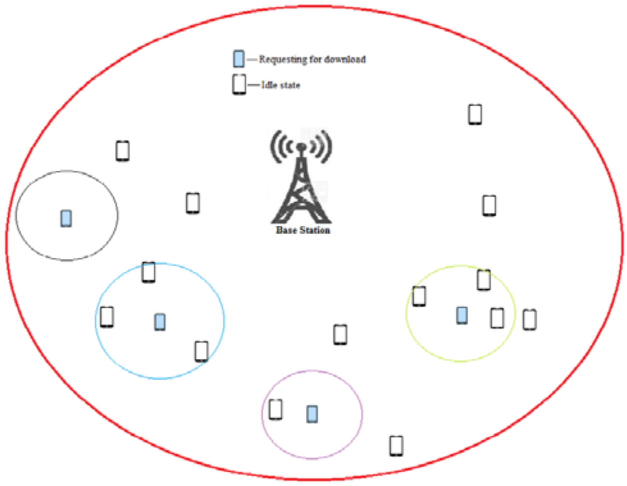

Figure 1 System Model

2. System Model of the Problem

Consider a cellular cell as shown in Fig. 1 with a traditional BS situated at center of the cell. There are M UEs with MIMO facilities distributed randomly within the coverage area of the cell and $\mathcal{M}$={1,2,.....,M}. The position of BS is considered as (0,0) and location of each UE i with respect to BS is (x_i, y_i). Let in a particular time t_0, N number of UEs request to the BS for downloading necessary contents with $\mathcal{N}$={1,2,.....,N}. The rest M-N UEs represented by $\mathcal{H}=\mathcal{M}\setminus\mathcal{N}$ are in idle state and can help $\mathcal{N}$ to attain better data rate by contributing there resources. The BS has $\mathcal{S}$={1,2,..,S} spectrum resources and employ orthogonal frequency division multiple access (OFDMA) mechanism for communication with the UEs.

So our first goal is to find out a set of UEs $H_i \subseteq H$ that can help UE i for gaining better throughput where $i \in N$. An UE $j \in H_i$ can assist UE i if it resides in it's local area of activity (LAoA) and is in idle state. If the radius of LAoA of UE i is r_i then UE j can join in cooperation if $d_{ij} \leq r_i$, where d_{ij} is the distance between UE i and UE j. The value of this assistance is the data rate achieved by UE i in a particular time.

3. Solution and Formulation

For finding $H_i \subseteq H$, we have used the skeleton of stable matching namely college admission problem [6] that can be solved by the deferred acceptance algorithm (DAA)[7]. There are two disjoint sets, exemplary requesting UEs N (acting as colleges) and helping UEs H (acting as students). The process is shown in Algorithm 1.

An UE downloads content independently using its own cellular connection through BS when there is no cooperation among the UEs. Take into account the case where cellular BS sends content to UE $i \in N$ with a carrier $s \in S$ directly with a data rate that can be calculated by using Shannon's capacity as shown in equation (1).

$$R_{i,dir} = W_d \log_2(1+\gamma_{i,0}^s) \qquad (1)$$

where W_d is the cellular down-link bandwidth dedicated for every link s, $\gamma_{i,0}^s$ is the signal to interference noise ratio (SINR) of UE i when downlink communication occurs with BS and $\gamma_{i,0}^s = \frac{P_{i,0} g_{i,0}^s}{\sum_{l \neq i, l \in N} P_{l,0} g_{i,l}^s + W_d N_0}$. Here $P_{i,0}$ is the amount of power involved at BS to send content to UE i using carrier s, $g_{i,0}^s$ is the channel gain between BS and UE i when carrier s is used and N_0 is the white Gaussian noise.

The given algorithm assigns H_i UEs to help requesting UE i. An UE $j \in H_i$ can get data $R_{j,0}$ from BS with a same rate as in equation (1). The transmission rate of UE j for UE i is shown in the equation (2) where W_u is the uplink bandwidth for any carrier $y \in S$. UE i gets data at a rate from UE j shown in the equation (3). So, UE i gets the total data rate directly from BS and indirectly from H_i UEs as a cooperation is shown by equation (4).

$$R_{i,j} = W_u \log_2(1+\gamma_{i,j}^y) \qquad (2)$$

$$R_{i,indj} = \min(R_{j,0}, R_{i,j}), \forall j \in H_i \qquad (3)$$

$$R_i = R_{i,dir} + R_{i,ind} \qquad (4)$$

where $R_{i,ind} = \sum_{j=1}^{H_i} R_{i,indj}$

Algorithm 1 Stable Matching

1: Input: M UEs
2: Each UE $i \in N$ sends request to the BS for downloading the contents and also broadcast the intension
3: Each UE $j \in H$ makes a preference list based on the received broadcast information of every i, and send to the BS
4: BS builds a preference list for every $i \in N$ depending on the received information from H
5: Repeat
6: Each UE $j \in H$ proposes to its most preferred UE $i \in N$ according to its preference list
7: If All the proposals don't violate the link capacity constraint of $i \in N$ Then
8: Every UEs $i \in N$ holds temporarily all the proposals
9: Else
10: Depending upon the preference list, every $i \in N$ holds the most preferred proposals that don't violate it's link capacity constraint i.e. quota
11: Every UE $i \subseteq N$ rejects other unacceptable proposals
12: End If
13: Until There is no proposals from the UEs H or the respective quotas are fulfilled
14: Output: Match, Σ

4. Simulation and Performance Evaluation

For the simulation, we model the locations of the UEs to be uniformly and independently distributed in a 500m radius space where BS stays in the center. Each UE has three connectivity: one for BS to UE communication and other two for UE to UE communication. We have considered 49dBm for macro BS and 20dBm for UE in LAoA as the transmit power with 20MHz bandwidth and 100 sub-carrier, half of which is used for UL and half for DL. For sketching the propagation environment, we use a path loss L(d)=34+40log(d) and L(d)=37+30log(d) for macro cell and LAoA respectively. We assume lognormal shadowing with a standard deviation of 8dB for macro cell and 4dB for LAoA. The power density of thermal noise power is -114dBm/Hz.

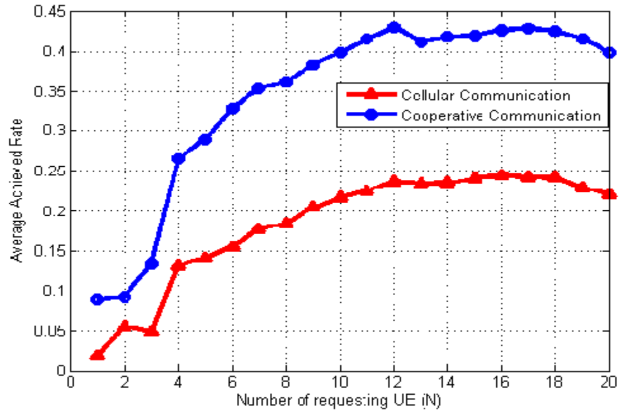

Figure 2 Comparison of performance when H=100, r=50m

Fig. 2 shows the performance of the cellular communication and cooperative communication when there are 100 helping UEs and radius of LAoA is 50m with increasing number of requesting UEs. From the figure, we see that average achieved rate is increasing with the increasing number of requesting UEs in both the case but the cooperative communication indicates better result than the traditional cellular communication. The improvement of cooperative communication is 81.11% when N=20 but this is about 105.43% on average in comparison to cellular communication.

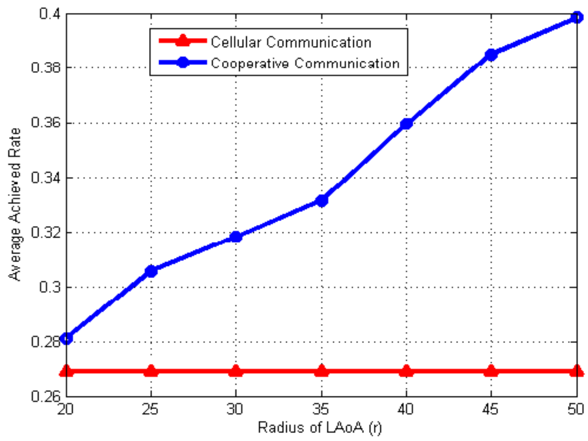

Figure 3 Comparison of performance when H=100, N=20

Fig. 3 represents the outcome of both methods when there are same number (like in Fig. 1) of helping UEs and N=20 number of requesting UEs with varying radius of LAoA from 20m to 50m. From the figure, we find that the achieved rate is enhanced dramatically with increased value of r in cooperative communication as the scope of cooperation is expanded. On the other hand, that rate is unchanged in traditional way. The percentage gain of cooperative communication than cellular communication is climbed linearly with r and this difference reached at 48.14% when r=50m.

Fig. 4 shows the average download time when a 100MB file is downloaded by varying number of the UEs. The figure reveals that the average download time is significantly reduced by cooperative communication and it takes 48.50% less time then cellular communication.

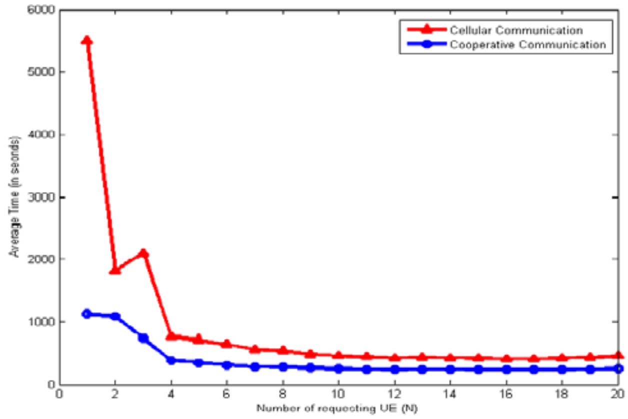

Figure 4 Comparison of average download time when H=100, r=50m

5. Conclusion

Cooperative communication can be an alternative to fulfill the QoS of the cellular users specially for data demanding applications. In this paper, we have formulated the problem as a matching game. Simulation results show that cooperative communication can give better data rate than traditional cellular communication and thus can made the users satisfied.

6. References

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