Improvement in Transmission Rate of Massive MIMO with ULA through Caching Technique

[1]Ankita Singh, [2]Kirit Kumar R. Bhatt, [3]Saurabh M. Patel
[1]Student member, [2]Faculty member, [3] Faculty member
[1]Electronic & Communication Department,
[1]Sardar Vallabhbhai Patel Institute of Technology, Vasad, India

Abstract: In this work we analyze the system performance of massive multiple input multiple output (MIMO) with uniform linear array (ULA) system by applying the wireless technique that is caching. As we know the existing mobile cellular network are changing(and getting better) toward 5G wireless network aiming to withstand with the gigantic growth of connected devices and data peckish applications of mobile handlers and we know this very well that spectrum are limited, so we have to improve the system performance for meeting the higher demand in wireless system. Among the possible solutions, edge caching at base station is an encouraging plan that can be responsible for better-quality of service. This work is target for Cache-aided communication which boosts the system performance by improving the transmission time and therefore reducing the congestion of network.

***Index Terms* - Edge caching, Cache-aided communication, MIMO**

I. INTRODUCTION

As per current scenario, the new wireless devices is become the fact of appearing everywhere or of being common. There is rapid increase of demand of smartphones which is easily accessible due to which social networking applications or bandwidth intensive applications increase rapidly. Therefore due to proliferation the network load increases exponentially as wireless data traffic is increases tremendously. Through rich media application, video streaming contribute maximum in data traffic as it account for almost 50% of mobile data traffic which is expected to increase tremendously in coming future. Also by the survey, the social networking also contribute second largest traffic volume. Therefore it is high demand to evolve the traditional cellular networks towards the next generation network which is referred as 5G networks for satisfying the high demand of data or fulfil the data crunch. So this data tsunami need to develop mobile operators in more advanced way to increase the coverage area of network and to boost the capacity of network more efficiently without much altering the cost and efficiency of system. As per current demand it is required to achieve better data transmission rate or provide maximum content to user in less time. So among all the demanding efforts caching the content of users' at the end of transmitter of network emerge as a possible solution for satisfying the mobile data tsunami [1][2].

By this promising content caching strategy, high demanding files are stored (cache) in the midway of servers or routers or base station (BSs) of antennas due to this the demands from users for same contents can be fulfilled easily without any delay from the servers and hence the superfluous traffic can be eliminated significantly. Hence in 5G mobile networks caching emerge as a potential technique for achieving the better and fast network condition [3].

As we know that the high data traffic is due to the facsimile downloads of a few popular files (e.g. viral videos or popular news) with hefty size. Therefore researchers and engineers have been studying or searching operative way to reduce the facsimile content transmission by putting into use storage related techniques referred as caching at the edge of wireless network namely at the level.

For reducing the multimedia traffic, the knowledge of caching at the transmitter end of network, namely at the level of base stations and user terminals has been drawing special attention in many works which includes edge caching, femto-caching[4] and proactive caching[5] which has capabilities to alleviate the backhaul loads and satisfy the users' demand.

The key restriction in the backhaul is the capacity and delays. Many literature works exist which focus on to mitigate the backhaul crunch by reducing the backhaul payload which is quibbling issue in 5G networks. Caching at the edge of BSs before transmission can significantly reduce the demand for backhaul resources by network. However for caching the memory of cache size is limited at the BSs. Therefore it is not realistic to store all the files at the BSs, as it is resource consuming, due to this cache placement approach must be carefully design to set of scales among the resource consumption and data transmission improvement. Making use of information of popular content for storing the data at the edge of network is utilized in the design of caching scheme would therefore develop a better system and conclude at improved system performance by analyzing the content popularity and demand of the user equipment which is requested most probably in peak duration, as the demand of the user depends on content which is popular or viral and the peak time of a day [6].

II. SYSTEM MODEL

In this system, we study a massive MIMO system having L number of transmitter and receiver pairs where base stations (BS) employ a uniform linear array. A ULA pattern having N_t antenna elements, which are evenly placed in a straight line with a gaps of d. For simplicity, here we adopt a homogeneous network where transmitter (having uniform linear array) have N_t antennas and all receivers (users) consist of N_r antennas. From transmitter k to its paired receiver k, the data streams are transmitted, these number of independent data streams is symbolized by d_k, with $d_k \leq \min(N_t; Nr)$. There is a channel between a single-antenna user and BS which can be characterized from the antenna array theory as [7]

$$\mathbf{h}_k = \int_{\theta \in A_k} \boldsymbol{\alpha_k(\theta) a(\theta)}\, d\boldsymbol{\theta}$$

where θ represent the direction of arrival (DOA) of each ray which is inside the incident signal and A_k is the angular spread (AS) of the incident signal from user-k. Here $\alpha_k(\theta)$ is the complex gain of the incident ray at DOA θ and a(θ) is the array manifold vector (AMV), whose expression is dependent on the array structure. When a uniform linear array is put into use,

$$\mathbf{a}(\boldsymbol{\theta}) = [\,1, e^{j\frac{2\pi d}{\lambda}\sin\theta}, \ldots\ldots, e^{j\frac{2\pi d}{\lambda}(M-1)\sin\theta}]^T$$

In ULA, the inter antenna spacing i.e. d has a linear relationship with λ (i.e. d= λμ) and λ is referred as carrier wavelength. We assume that the users are unsystematically spread inside the cell, and hence azimuth angles track a uniform distribution in the [0, 2π] interval. Then the probability density function (p.d.f.) of the users' azimuth angles ϕ_k ($\forall k = 1, ., K$) can be describe as

$$f\,(\phi_k) = \frac{1}{2\pi}.$$

Here ϕk represent the azimuth angle of the AoD of the k-th user.

III. Cache-Aided System

One of the promising solutions of cache aided system is to accomplish remarkable achievements in terms of users' contentment and reducing data traffic at lower cost by edge caching where content files are cached at local BSs for the future transmission process. It helps to achieve improved multicast throughput and efficiency and also achieve better interference management with lower cost and balanced resource consumption.

Note that size of cache is limited so memory should be allocated efficiently. The popular files are more probable to be requested over large time period by many users equipment due to its high demand. Therefore efficiently use the files popularity information in storing the data which leads to better system performance at lower cost. The files to be cached were first categorized into two sets according to their popularity i.e. popular set and less popular set. For efficiently using the limited storage resources is to cache more files which come under popular set at all base station, where the files which come under less popular sets are cached at only part of the base station tactically which minimize the congestion of network by adjusting the popular file placement factor. For achieving content gain and network gain, the edge caching utilize the most popular content (MPC) strategy and largest content diversity (LCD) strategy. Whereas MPC and LCD is not the best choice for caching in terms of quality of service of overall system. As in MPC only the most popular content are cached which ignore the no popular content which is not efficient for all type of users demand in all over time span. Also in LCD which focus on all content to cache at all base station which is not efficient when non popular files take more storage space in caching at all base station i.e. not in high demand and waste the consumption of resources.

IV. Cache Enabled Base Station

In several work, the notion of caching is highlighted at the transmitter end of network which referred at the edge of base station and user equipment. Various studies shows that multiple users demand the same content frequently on the basis of popularity of content such as new blogs, multimedia streaming, case of viral videos or latest news. In this circumstance, the network will be flooded with similar request of file which lead to delay before a transfer of data begins following an instruction for its transfer or congestion of network. So it is essential to proper distribution of content on the basis of the worldwide content popularity distribution. As stated above, the idea behind having cache-enabled BSs is to store (cache) locally at the BSs allocating certain sort of user who request for general high demand file. Let take to be true that each BS is well-found with a place for storage unit (hard disk) which is referred as catalog in which store the popular file. Meanwhile the storage capability cannot be infinite as it has some limit, so assume that at each BS has a group of file in order up to f_0 (the catalog) is stockpiled on the storage unit. Rather than storing (caching data) evenly the entire file, a smarter method will be to cache the most requested file according to the given worldwide file popularity figures. The model of the file popularity distribution of a certain sort of user to be a right continuous and monotonically decreasing process how probability distribution function (PDF) use represented as [8]

$$f_{pop}\,(f, \eta) = \begin{cases} (\eta - 1) f^{-\eta}, & f \geq 1, \\ 0, & f < 1, \end{cases}$$

here *f* represent a point in the support of the corresponding content, and Ƞ represents the steepness of the popularity distribution curve.
Here the Ƞ steepness factor is well-defined as the (average) number of users per BS. The reasoning for the above model is that the more number of file requested by user which is cache at the BS, the more precisely the general direction is made selections which is based on content popularity and hence for this reason more file(content) is organized for the left of the distribution there by making it more sharply sloping. Now the chance of what is requested by a connected user falls within the range [0; f_0] which is lies in the size of storage unit (catalog) is given by

$$P_{hit} = \int_0^{fo} f pop\,(f, Ƞ)\, df$$
$$= \int_0^{fo} (Ƞ - 1) f^{-Ƞ}\, df$$
$$= 1 - fo^{1-Ƞ}$$

It can be verified that P_{hit} converges to 1 when the file (catalog) stored in the BSs goes to unlimited and it is referred as hitting probability. Consequently, the probability of a non-popular file that is referred as a request is missing from the catalog can be expressed as P_{miss}.

$$P_{miss} = 1 - P_{hit}$$
$$= fo^{1-Ƞ}.$$

V. PERFORMANCE ANALYSYS

The total average transmission rate denoted as $\bar{r}$Ts is an increasing function with respect to the number of pairs L (with L≥ 3), The total average transmission rate is given by

$$\bar{r}Ts = \begin{cases} 2a\sum_{i=1}^{\frac{L}{2}} e^{a_i} E_1(a_i) + b & \text{if L is even} \\ 2a\sum_{i=1}^{|L/2|} e^{a_i} E_1(a_i) + ae^{b1} E_1(b_1) + b & \text{if L is odd} \end{cases}$$

Where $a_i = d\,\sigma^2 P^{-1} + d2^{1-B/Q}(1-\zeta)^{-1}(2\zeta-\zeta^{L-i+1}-\zeta^i)$, $b_1 = d\,\sigma^2 P^{-1} + d2^{1-B/Q}(1-\zeta)^{-1}2(\zeta-\zeta^{|L/2|+1})$, $a = d\log_2(e)(1-f_o^{1-Ƞ})$ **and** $b = C_d f_o^{1-Ƞ}$ **and** $Q = N_t N_r - 1$.

Here P is referred as total power at each transmitter equally assigned among its streams. The value of ζ is small as it represent the path loss of channel, so we assume it 0.1. Here *e* is quantization error [9][10] and C_d as the part of the capacity dedicated to data transfer.
The more place for storing (caching) amount is increases, more lost chance drops, and therefore the probability of striking increases. In this way, the total average transmission rate is effectively influenced cached file because a fixed slope (steepness factor) has a support of cached file (represented by fo).

VI. NUMERICAL RESULTS

In this segment we show our numerical results to validate the study done in the earlier section. For ease of clarification, we consider a setup.

Table 1: System setting for simulation.

Number of transmitting antenna N_t	64
Number of receiving antenna N_r	64
SNR = $\log_{10}(P/\sigma^2)$	20dB
Path loss of channel ζ	0.1
Cd	10 Mb/s
Number of bits B	50 bits
Bandwidth (per transmitter)	10 MHz
Number of data stream	4
Time slot (τ)	1 ms

In Fig. 1 we plot the variation of the total average transmission rate with respect to the number of active pairs L. It can be seen that $\bar{r}$Ts is increases with L.

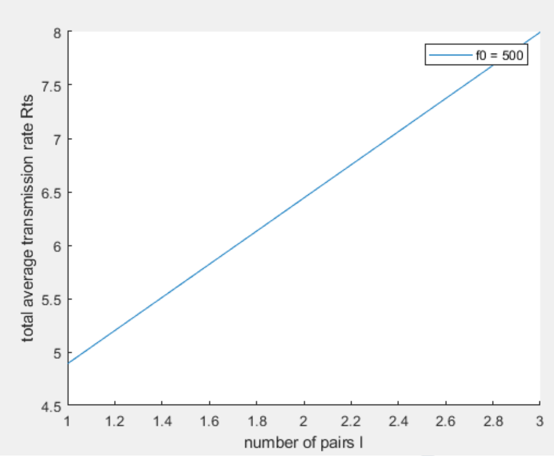

Fig 1: Total average transmission rate versus number of active pairs L.

VII. CONCLUSION

In this paper we have analyses the system performance of massive MIMO with uniform linear array by applying the caching at the base station at transmitter end. We observed that under the cache enabled base station, with increased number of L pairs the total average transmission rate increase. As we observed that the transmission rate depends on f_o (catalog size), steepness factor Ƞ and number of pairs. The more caching capacity (catalog size) increases, the more hitting probability increases as it store more popular content and therefore missing probability decreases. Therefore for a fixed steepness factor Ƞ, the support of catalog contents has an important effect on the total average transmission rate.

REFERENCES

[1] X. Wang et al., “Cache in the Air: Exploiting Content Caching and Delivery Techniques for 5G Systems,” IEEE Commun. Mag., vol. 52, no. 2, Feb. 2014, pp. 131–39.

[2] M. Ji, G. Caire, and A. Molisch, “Wireless Device-to-Device Caching Networks: Basic Principles and System Performance,” IEEE JSAC, vol. 34, no.1, Jan. 2016, pp. 176–89.

[3] F. Zhou, L. Fan, N. Wang, G. Luo, J. Tang, and W. Chen, ``A cache aided communication scheme for downlink coordinated multipoint transmission," IEEE Access, vol. 6, pp. 1416-1427, 2018.

[4] N. Golrezaei et al., “Femtocaching and Device-to-Device Collaboration: A New Architecture for Wireless Video Distribution,” IEEE Commun. Mag., vol. 51, no. 4, Apr. 2013, pp. 142–49.

[5] E. Bastug, M. Bennis, and M. Debbah, “Living on the Edge: The Role of Proactive Caching in 5G Wireless Networks,” IEEE Commun. Mag., vol. 52, no. 8, Aug. 2014, pp. 82–89.

[6] A. Tatar et al., “A Survey on Predicting the Popularity of Web Content,” Springer J. Internet Services and Applications, vol. 5, no. 1, 2014, pp. 1–20.

[7] C. Sun, X. Q. Gao, S. Jin, M. Matthaiou, Z. Ding, and C. Xiao, ``Beam division multiple access transmission for massive MIMO communications,"IEEE Trans. Commun., vol. 63, no. 6, pp. 21702184, Jun. 2015.

[8] Matha Deghel, Ejder Baştuğ, Mohamad Assaad, Merouane Debbah, “On the Benefits of Edge Caching for MIMO InterferenceAlignment,”arXiv:1506.04583v2 [cs.IT] 16 Jun 2015.

[9] T. Yoo, N. Jindal, and A. Goldsmith, “Multi-antenna downlink channels with limited feedback and user selection,” IEEE Journal on Selected Areas in Communications, vol. 25, no. 7, pp. 1478–1491, September 2007.

[10] K. Huang and V. Lau, “Stability and delay of zero-forcing SDMA with limited feedback,” IEEE Transactions on Information Theory, vol. 58, no. 10, pp. 6499–6514, Oct 2012.

[11] T. Gou and S. A. Jafar, “Degrees of freedom of the k user M×N MIMO interference channel,” IEEE Transactions on Information Theory, vol. 56, no. 12, pp. 6040–6057, December 2010.