Analysis of Beam Division Multiple Access in Massive MIMO Communication Systems

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ABSTRACT

The main objectives in wireless communication, mostly after the 4G systems introduction are increased channel capacity, improve data rate, decrease in latency and better quality of services. Hence drastic improvements need to be made in architecture of the cellular network to meet up these demands.This paper presents the information of massive Multiple Input Multiple Output (MIMO) system that consists of hundreds of antenna elements. With advanced access technology namely Beam Division Multiple Access (BDMA), the Base station (BS) serves as multiple users. The BDMA technique serves multiple users simultaneously by focusing parts of an antenna beam towards the position of the mobile user devices thereby giving multiple accesses to mobile users and hence increasing the capacity of the system significantly. The antenna beams can be steered to desired direction depending on traffic environment and nulls are placed in undesired direction. Thus the problem created by intended jammers are considerably reduced.

***Keywords:* 4G, Massive MIMO, BDMA.**

INTRODUCTION

In wireless network it is observed exponential growth in increase of mobile devices and wireless data rate so that the manufacture and operators face a major problem to offer sufficient network capacity due to rise in traffic day by day. In order to address this demand, Massive MIMO (Fig.1) used must face challenges like network coverage, energy efficiency, network capacity, network reliability and latency.[1]. Massive MIMO at Base Stations make use of tens or hundreds of antennas to significantly increase gain in link reliability and data rates by adapting Direction of Arrival (DOA) and Adaptive Beam Forming (ABF) algorithms. The DOA provides information about the direction of the arrival of the wave and hence the source location. This enables steering of the antenna array in the direction of the source.

The BDMA (Fig.2), after evaluating mobile device location allocates, part of antenna beam whereas the same beam will address the mobile devices located at the same angle hence increasing capacity[2].

BEAM DIVISION

In sensor array, beam forming is used for direction transmission or reception of signal. This is done by adding elements of phased array, so that at particular angles, signals experience constructive interference whereas destructive interference is experienced by others. Thus it is used to obtain spatial selectivity. Beam forming techniques are of two types[3]:

- Switched Beam forming
- Adaptive Beam forming

Switched beam forming makes use of fixed set of time delays and weights to add the signals from array of sensors. Adaptive beam forming can adapt its response automatically to different direction.

ADAPTIVE FILTER

The adaptive filter adjusts filter coefficient by itself according to adaptive algorithm and eliminates the interference signal from desired signal that are received at the sensors as power spectrum continuously changes with time. Thus weights are updated continuously and are adapted in the direction of signal received[4].

MASSIVE MIMO APPLICATIONS

Massive MIMO offers increase in network coverage, signal quality and capacity of wireless systems. Used in solar systems, radar systems, spacecraft, aircraft as narrow beam can be targeted in desired direction. To communicate with satellite massive MIMO antennas can be used in ground station.[5]

PREVIOUS SYSTEMS

In Weighted Minimum Mean Square Error (WMMSE) systems, the inverse of array correlation matrix becomes infinity as a result the beam is radiates in all directions not only towards the desired user. Even the inference jammers also get the radiated signal[6-7].

CURRENT SYSTEMS

In BDMA, the main beam in radiation pattern is directed only to the desired users while nulls are placed in the direction of interfering signals including jammers. The Mean square error in BDMA network is very less[8]. Variable step size (VSS) algorithm is used in BDMA that solves the existing issues of error and convergence, reducing error and increasing convergence rate and thus interference handling ability is improved and interfering and irrelevant noises are eliminated.

WMMSE DOWNLINK

In order to find the direction of desired mobile user that is downlink, array weight from -90 degree to +90 degree is calculated using WMMSE algorithm. Initially for desired path Px1 steering vectors are calculated, where P is the number of antenna array. Then PxQ array vector related to 'Q' source of interference directions i.e., $\theta 1, \theta 2......\theta_Q$ are calculated. The desired signal 'H' from baseband frequency is obtained. Calculate the autocorrelation matrix S_{yy} of desired signal.

The step size is given by

$$\delta = 2/3tr(s) \quad (1)$$

The received signal is given

$$y(n)=h(n)a(\theta o)+\sum_{i=1}^{Q} i_i(n)a(\theta_i)+n_0(n) \quad (2)$$

where a (θo) is the steering vector of desired signal ,$a(\theta_i)$ the steering vector of i^{th} interference sources, Q is the jamming sources and $n_o(n)$ is the noise signal.

Weiner Hopf equation

$$w(n)=S^{-1}_{yy} S_{hy} \quad (3)$$

Where S_{yy} is the auto correlation of received signal and S_{hy} is the cross correlation of desired signal.

The updated weight is computed by

$$z(n)=w(n)^H y(n) \quad (4)$$

Where z(n) is array output.

$$c(n)=h(n)-z(n) \quad (5)$$

Where c(n) gives the mean square error.

$$w(n+1) = w(n)+\frac{\delta}{\alpha_1 c(n)c*(n)+(1-\alpha_1)c(n)c*(n)}c*(n)*y(n) \quad (6)$$

Where 'α' is the current step size correlation to the step of previous that ranges from $0<\alpha<1$.

For all angle θ array factor is computed and beam is scanned according to array weight. After tracking the direction of mobile user the main beam is directed to the user mobile detected (Fig 3).

VSS BDMA ALGORITHM

With VSS BDMA, misadjustment can be reduced and convergence rate can be enhanced. The autocorrelation is given as

$$S=E[y(n)y(n)^H] \quad (7)$$

Where y(n) is the received signal and hermitian transpose of y(n) is given as $y(n)^H$.

Throughout iteration, the step size is computed.

$$\delta(n+1) = \alpha\delta(n) + \gamma|c(n)|^2 \quad (8)$$

'γ' indicates the convergence characteristic control in VSS BDMA. Where γ=0.5.

The step size upper bound is given by

$$S_{upper}=\frac{2}{3tr(cov(y))} \quad (9)$$

Where tr(cov(y)) is the covariance matrix trace of received signal 'y'.

The updated weight to focus the main beam to the desired mobile direction and nulls in undesired direction by making use of VSS BDMA algorithm is given as

$$w(n+1)=w(n)+\delta(n+1)c(n)y(n) \quad (10)$$

The step size throughout iteration is updated as

$\delta(n+1)=\delta_{upper}$ if $\delta(n+1)> \delta_{upper}$ (11)

$=0$ if $\delta(n+1) <0$ (12)

$=\delta(n+1)$otherwise (13)

By comparing equations (6) and (10) it is observed that equation (10) has smaller step size thus mean square error becomes minimum and convergence rate maximize.

MOBILE DETECTION

In WMMSE, mobile is detected based on the power spectrum that depends on the Maximum Eigen Value, whereas in BDMA it is based on the noise Eigen Vector that assume noise are uncorrelated in channel[9-10].

CONCLUSIONS

In this work, information about Massive MIMO having large antenna array at BS making use of BDMA to increase the capacity, data rate quality of service and decrease latency has been explained. BDMA that form narrow beam towards the desired direction providing multiple access to users and prevent intended jammers by placing nulls.The weights are updated continuously as signal received and form beam without misadjustment. BDMA is compared with WMMSE algorithm results that BDMA has maximum convergence rate and minimum mean square error than WMMSE.

ACKNOWLEDGEMENTS

I would like to thank BSNL RTTC Myuru, for their constant support and assistance in doing this project.

REFERENCES

[1]http://www.radioelectronics.com/info/antennas/mimo/large-massive-mimo-systems.php.

[2]http://www.rfwirelessworld.com/Terminology/what-is-BDMA.

[3] https://en.wikipedia.org/wiki/Beamforming

[4]https://en.wikipedia.org/wiki/Adaptive_beamformer

[5] E. G. Larsson, F. Tufvesson, O. Edfors, and T. L. Marzetta, "Massive MIMO for Next Generation Wireless Systems," *IEEE Communications Magazine*, vol. 52, no. 2, pp. 186-195, February 2014.

[6] Søren Skovgaard Christensen, Rajiv Agarwal, Elisabeth de Carvalho, and John M. Cioffi "Weighted Sum-Rate Maximization using Weighted MMSE for MIMO-BC Beamforming,"IEEE Transactions On Wireless Communications, Vol. 7, No. 12, December 2008

[7] H. Weingarten, Y. Steinberg, and S. Shamai, "The capacity region ofthe gaussian multiple-input multiple-output broadcast channel," IEEE Trans. Inform. Theory, vol. 52, no. 9, pp. 3936–3964, Sept. 2006.

[8] Chen Sun, "Beam Division Multiple Access Transmission for Massive MIMO Communications" IEEE Transactions On Communications, Vol. 63, No. 6, June 2015

[9] X. Li, S. Jin, and X. Q. Gao, "Multi-user MIMO downlink eigen-mode transmission over jointly correlated MIMO channels," Sci. China Inf. Sci.,vol. 54, no. 10, pp. 2124–2137, Oct. 2011

[10] X. Q. Gao, B. Jiang, X. Li, A. B. Gershman, andM. R.McKay, "Statistical eigenmode transmission over jointly correlated MIMO channels," IEEE Trans. Inf. Theory, vol. 55, no. 8, pp. 3735–3750, Aug.2009.

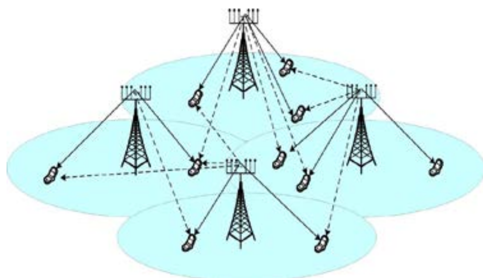


Fig.1.Massive MIMO Systems

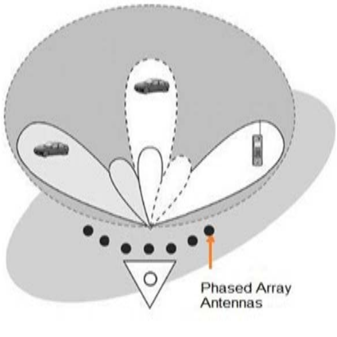
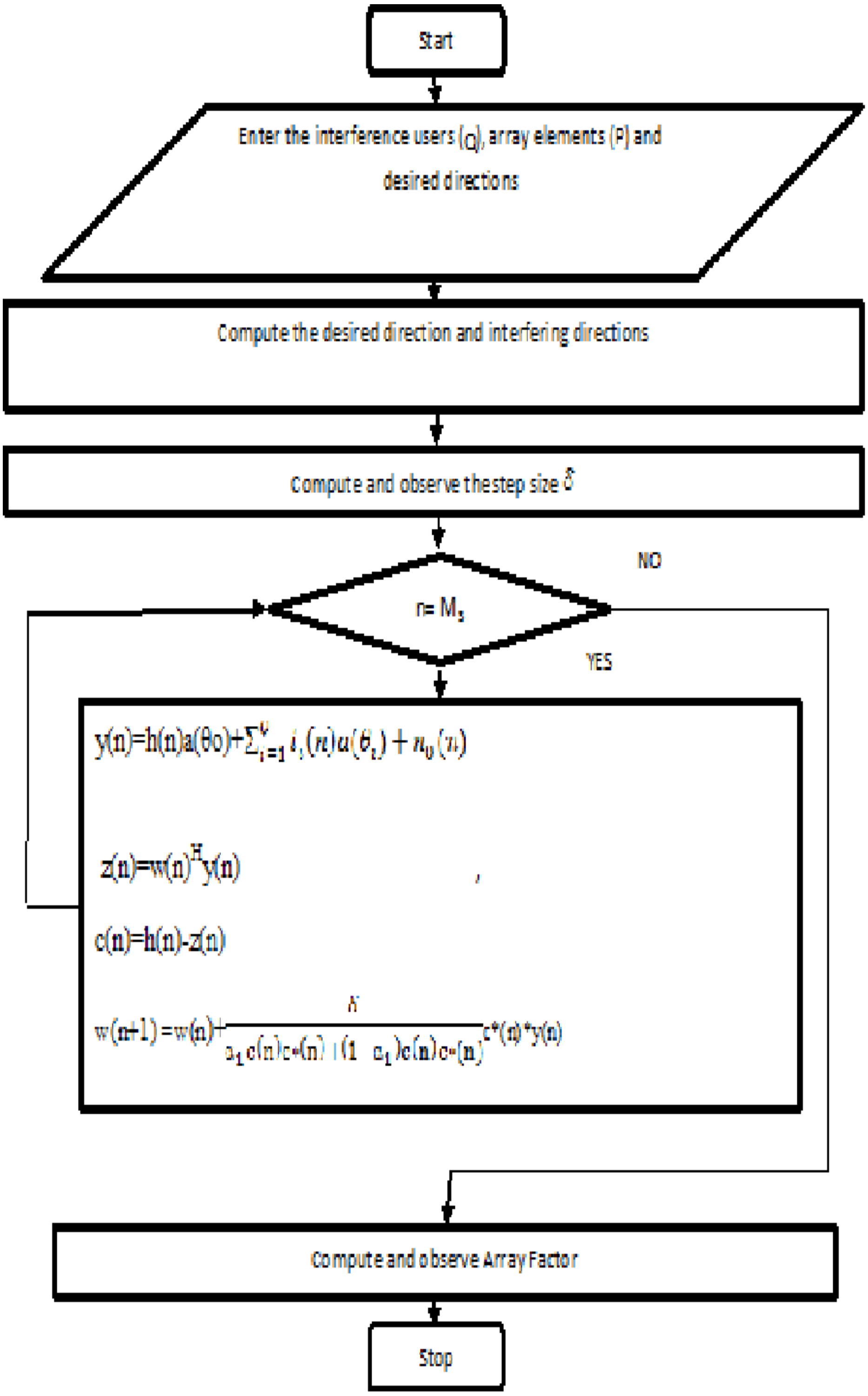


Fig.2.BDMA


Start
Enter the interference users (Q), array elements (P) and desired directions
Compute the desired direction and interfering directions
Compute and observe the step size δ
n= M
NO
YES
Compute and observe Array Factor
Stop