Guided MAC to Enhance Quality of Experience of Video Data Transmission over Massive MIMO

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Abstract. Massive MIMO (M-MIMO) system contains hundreds of antennas at base station to achieve large gains in spectral-efficiency when compared with conventional MIMO technology. High speed and Quality of Experience (QoE) of video data over wireless communication has always been a challenge for the researchers due to scarcity of the bandwidth, fading and interference. Noisy channels corrupt the transmitted video and results in poor QoE at the receiver. Therefore, to maintain the QoE of the video, it is highly desirable to identify noisy channels and avoid transmission over them. In the proposed approach, the channels are categorized into two categories: good or bad. If SINR value is greater than threshold value a channel is good otherwise bad. A Guided MAC layer (GMAC) protocol is designed to transmit the video data over good channels only and to discard the transmission over bad channels.

Keywords: Massive MIMO, QoE, Channel State Information, MAC Layer.

1. Introduction
With improved wireless technologies in society the demand of video transmission is increased. Therefore, the wireless internet devices face the demand of proliferating high data rate services. The experts of wireless industries have reached the conclusion that incremental technologies (1G to 4G) fail to meet the data demands of foreseeable future. A 4G system must carry abilities defined by ITU in Advanced. Various challenges addressed in 4G are: 1) High data rate, 2) High Mobility, 3) High capacity, 4) Lower E2E delay, 5) and massive device communication. The current existing technology i.e., 4G uses Conventional MIMO which uses at most 4 antennas for transmission of data. By which it fails to transmit a high quality data (HD+ video) with low latency. Other challenges include, higher data rate, low end to end latency, low cost, massive device communication with better QoS [3]. So, to overcome these challenges a next generation technology (5G technology) is required. 5G inventions allow the world with huge capacity, massive connectivity & future internet [1].

5G technologies are based on BDMA technology. According to BDMA technique, a beam is divided according to the location of mobile station. It is commonly assumed that 5G cellular network must address the challenges which are not effectively addressed by 4G [1].

Evolution of new wireless technologies in the past and current decade gave significant growth of different wireless networks 5G technologies, like Massive Multiple Input Multiple Output (M-MIMO), millimeter waves (mm Waves), Machine to Machine communication (M2M communication) etc., which have facilitated fast data transmission between the communicating
devices with certain challenges like interference and pilot contamination. M-MIMO communication uses large number of antennas at the base stations (BS) to serve the users. Therefore, M-MIMO can be a promising technology of the future having large potential of high data speed, energy efficiency and spectral efficiency.

While promising technology, transmission of video data over M-MIMO still presents various research challenges like poor QoE. We have proposed a method to reduce the co-channel interference and enhance the quality of the transmitted video. In this paper, we have used Channel State Information (CSI) to observe the status of various channels and categorize them as good or bad. Transmissions over good channels reduce packet error and retransmissions of the corrupted packets which result in effective bandwidth availability. The guided MAC mechanism of the proposed method restricts the admission of the packets over bad channels.

This paper is organized as follows: in Section II, literature survey is done, Section III describes the proposed work, Results are analyzed in section IV and finally we conclude the work in Section V.

2. Literature survey

The review has revealed the challenges in low-latency transmission and improving QoE of video data over MMIMO. Authors [1] have proposed a QoS aware cell association mechanism using Massive MIMO. In [1], a user selects a cell in HetNet, based on the data rate broadcasted by the all available cell and then calculate average data rate, If the required data rate is less than the calculated one, user switches to other cell. An interference reduction in multi cell MIMIO system using outer multi-cellular pre coding is proposed in [2]. The authors have used Large Scale Fading Pre coding for combining messages obtained from different cells. An energy efficient approach is presented in [3] for a macro-cell network. Authors offered a densified topology that enables very high spatial reuse and minimize the energy consumption without affecting QoS. [4] is a QoS-based Joint User Selection and Scheduling approach for MU-MIMO. The authors have focused on Joint User Selection and Scheduling (JUSS) in place of gathering Channel State Information (CSI)from all users to avoid overheads. Interference issues in Random Access Network are addressed in [5] through interference management schemes. This paper elaborates three interference management drivers, for service-tailored optimization to improving cell-edge throughput, energy-efficiency and minimizing the signaling overhead using Base Station (BS) clustering and context-awareness.

Lu Lu et al. [6] discuss the pilot contamination effect in massive MIMO. The major problem faced in massive MIMO is pilot contamination. In massive MIMO Pilot sequence used by user should be orthogonal within the same cell and the neighboring cells. But within a given bandwidth the number of orthogonal Pilot sequences is limited. In [7], the authors have found the tradeoffs between delay, throughput, and the accuracy/complexity of CSI acquisition in M-MIMO cellular network systems. Authors have characterized the queue-lengths scaling performance and the congestion control rate scaling performance to show the transitioning phenomenon in the steady-state queue-length deviation in CSI. Authors [8] have studied over Massive MIMO and suggested different challenges like channel reciprocity, pilot contamination. In [9] authors start with analysis of information theory to illustrate the conjectured advantages of massive MIMO and addressed implementation issues like channel estimation, detection and pre coding schemes. Authors [10] have presented the summary of existing video transmission methods based on SVC over MIMO systems using cross-layer designs and focused on content-based transmission.

Many authors suggested different methods to tackle the problem of Quality of Experience (QoE) of the transmitted video. These protocols are designed to solve the problem of video quality but do not take account to avoid channel noise to improve quality of video. Hence, decision made to improve QoE of a transmitted video is not correct. The proposed protocol consider noise on all channels between transmitter to receiver and then takes decision for selecting good channels among all available channels for video transmission.

3. Proposed work
We assume a two-dimensional cellular network composed of ‘k’ hexagonal cells with one base station and ‘n’ users in each cell. There are ‘M’ antennas at the base station and one antenna at the user equipment (UE).

This section proposes a mathematical model for the hypothesis of classifying the channels in good or bad category and observing the QoE at the receiver. Estimating expected PSNR at receiver before transmission over a specific channel offers a better solution to decide whether to transmit over that channel or not. The proposed protocol considers the small/large scale fading channel model to transmit a video over it. The results obtained in this work outperform from the existing Massive MIMO technology. [9-19].

A. System Model

We consider SU-MIMO systems with L cells, where each cell has ‘K’ single-antenna users and one BS with ‘N’ antennas. Denote the channel coefficient from k-th user in the l-th cell to the n-th antenna of the i-th BS as hi,k,l,n, and is modeled as

\[ h_{i,k,l,n} = g_{i,k,l,n} \sqrt{d_{i,k,l}} \]  

(1)

Where \( g_{i,k,l,n} \) and \( d_{i,k,l} \) denote complex small scale and large scale fading coefficients, respectively.

The channel matrix for all K users in l-th cell to i-th BS can be given as

\[ H_{i,l} = G_{i,l} \times D_{i,l}^{1/2} \]  

(2)

where \( G_{i,l} \) and \( D_{i,l} \) are complex small scale and large scale fading. The channel matrix \( (H) \) is given as:

\[
\begin{bmatrix}
    h_{11} & h_{12} & h_{13} & \cdots & h_{1nT} \\
    h_{21} & h_{22} & h_{23} & \cdots & h_{2nT} \\
    h_{31} & h_{32} & h_{33} & \cdots & h_{3nT} \\
    \vdots & \vdots & \vdots & \ddots & \vdots \\
    h_{nRx1} & h_{nRx2} & h_{nRx3} & \cdots & h_{nRxnT}
\end{bmatrix}
\]

(3)

Here \( h_{ij} \) represents the channel between \( i^{th} \) and \( j^{th} \) antennas of transmitter and receiver, respectively.

B. Calculation of Good and Bad Channels

Let \( X(t) \) be the transmitted signal from a transmitter equipped with an array of \( N_T \) transmitting antennas then the received signal \( Y(t) \) at a receiver with an array of \( N_R \) receiving antennas can be given as follows:

\[ Y(t) = H \times X(t) + n(t) \]  

(4)

Here \( n(t) \) is a zero mean noise vector with complex Gaussian distribution and calculated as follows:

\[ n(t) = \text{mean} + sd_{\text{dev}} \times \text{randn} \]  

(5)

Based on the channel strength (CSI), channel matrix \( (H) \) is categorized into good and bad channels. If signal strength \( (Y(t)) \) received at the receiver is greater than or equal to a QoE threshold value \( (QoE_{\text{Th}} = 25 \text{ dB, acceptable signal strength as per ITU}) \), for a given input signal \( X(t) \), channels are categorized as good otherwise bad :

\[
H_{\text{good}} = \begin{bmatrix}
    g_{11} & g_{12} & g_{13} & \cdots \\
    g_{21} & g_{22} & g_{23} & \cdots \\
    g_{31} & g_{32} & g_{33} & \cdots \\
\end{bmatrix}_{p \times s} \quad \quad \quad H_{\text{bad}} = \begin{bmatrix}
    b_{11} & b_{12} & b_{13} & \cdots \\
    b_{21} & b_{22} & b_{23} & \cdots \\
    b_{31} & b_{32} & b_{33} & \cdots \\
\end{bmatrix}_{u \times v}
\]

(6)
Here $H_{\text{Good}}$ and $H_{\text{bad}}$ are the matrices representing a set of \textit{good} and \textit{bad} channels, respectively, depending upon the received signal value at the receiver.

**Algorithm**

1. Let $T$ be the transmitter and $R$ be the receiver with $M$ and $N$ antennas, respectively.
2. $\text{CSI}_{th} = 25 \text{dB}$ \hspace{1cm} //CSI Threshold
3. $H_{MN} = G_{MN} \times D_{MN}^{1/2}$ \hspace{1cm} // CSI Estimation
4. for $i=1$ to $N_T$ do \hspace{1cm} //nos. of antennas at transmitter
5. for $j=1$ to $N_R$ do \hspace{1cm} // nos. of antennas at receiver
6. $Y_{ij} = H_{ij} \times X_{ij} + n(t)$ \hspace{1cm} //Signal Estimation at sender
7. If $Y_{ij} \geq \text{CSI}_{Th}$ then \hspace{1cm} //Channel Categorization
8. $H_{\text{Good}}(i,j) = H(i,j)$
9. Else $H_{\text{Bad}}(i,j) = H(i,j)$.
10. End if
11. End for
12. End for

// Channel Accessing by GMAC for data transmission over Good Channel
13. for $i=1$ to $N_p$ do
14. for $j=1$ to $N_x$ do
15. $Y_{ij}(t) = H_{\text{Good}}(i,j) \times X_{ij} + n(t)$
16. If $Y_{ij}(t) > 25 \text{ dB}$ then
17. Channel is available for Video transmission
18. Else
19. Channel is avoided for Video transmission
20. $Y_{ij}(t)$ is recalculated after $\delta t$ time
21. Endif
22. End for
23. End for
24. End.

Fig. 1 GMAC Algorithm

The proposed method forces MAC layer to access the good channels and transmit the video data over these channels only and avoid transmission over bad channels to achieve required acceptable QoE. Therefore, to obtain acceptable good quality at the receiver eq. (4) is modified as follows:

$$Y(t) = H_{\text{good}} \times X(t) + n(t)$$

Where $H_{\text{good}} \geq \text{CSI}_{Th}$ \hspace{4cm} (7)

1. **Channel Accessing Scheme of MAC Layer**

**Guided MAC**

Medium Access (MAC) layer of the proposed approach is designed to checks whether the available channels are \textit{good} or \textit{bad} channels depending upon the CSI threshold value, and make available the \textit{good} channels only to the station which wins the contention. The stations who do not get channels access take a random backoff. Bad channels are discarded by the MAC layer for the current transmission and reestablishes the good and bad channels for a new flow.
4. Results
This section discusses about results analysis and validation carried out for the proposal. NS-2 is used to simulate the environment. A network of ‘50’ stations connected via base stations having a matrix of 64×64 antennas. A 40 dB video is transmitted over the noisy channels having noise ranging from 15dB to 50dB. The PSNR values obtained at receiver using proposed protocol and limited CSI information [7] are compared in Fig. 3. A video packet received at receiver having PSNR greater than 25 dB is acceptable and found with satisfactory QoE.

A. All channels are noiseless

![Limited CSI Vs GMAC](image)

Fig. 3: PSNR value received at receiver in noiseless channels
Fig. 4: PSNR Value of the received packet at Receiver in noisy channels

The performance of both the methods, Limited CSI and GMAC is observed same when channels are noiseless (Fig. 3). The QoE of the video packets transmitted over noiseless channels and received at receiver is obtained greater than 25 dB in both the methods. GMAC behaves similar to Limited CSI method and transmit data over all channels without excluding any channel.

B. Channels are noisy

In the simulated environment channels, some of the channels are assumed noisy for time span 500ms with signal strength below 25 dB. PSNR values of the transmitted video packets are compared at receiver with the PSNR values at sender. From Fig. 4, it can be observed that PSNR value of the received packet at receiver is obtained better in the proposed GMAC method because it excludes the noisy channels from the transmission process and forward the packets to noiseless channels (if any) for transmission.

Packets are transmitted over all 64 channels in limited CSI information method; therefore, the PSNR obtained of the packets which are passed through the noisy channels is low and hence contribute to bad QoE. It can be observed from the Fig. 4 that some of the packets (packet nos. 21 to 25, 50, 51 and 60) are poor QoE (below 25 dB) at receiver. Therefore, The QoE in Limited CSI method is observed poor as compared to proposed GMAC method. On the other hand, GMAC keep on calculating CSI of the channels after every 500ms and stop transmission over a channel if its CSI goes below 25 dB. From the Fig. 4, we can observe that all packets are having satisfactory or good QoE (PSNR > 25 dB).
Fig. 5 (b): A Video frame received at receiver in Limited CSI Method

Fig 5 (c): A video frame in GMAC Method

Fig. 6: End to End Delay in Limited CSI and GMAC

Fig 5 (a) is an actual video frame which is transmitted using both the methods; the frame Fig. 5 (b) and Fig. 5(c) are received at receiver using Limited CSI method and GMAC respectively. From the Fig. 5 (b) and Fig. 5 (c), it can be observed that frame QoE in GMAC is better than Limited CSI.

End to End delay in GMAC is 30% higher than Limited CSI method as number of available channels for transmission is less and more packets are sent on single channel. But this high end to end delay (E2E) (maximum up to 10ms, Fig. 6) is observed within the limit and does not make any effect on the QoE.

5. Conclusion and future work
Proposed GMAC method for channel accessing addresses the challenges of QoE for video transmission over Massive MIMO. GMAC outperforms the existing Limited CSI method with high (30%) end to end delay. GMAC supports the importance of channel state information to transmit the data. GMAC discard the packet transmission and do not work when all the channels are noisy (< 25 dB). We leave this to the future researchers to contribute and find the solution.

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