Adaptive Beamforming towards 5G systems

Whitepaper
Abstract

MIMO has been the undisputed candidate for wireless communications. It provides high diversity order and increased data-rate. Beamforming is a technique that helps to exploit the channel and minimize the inter-user interference among the cells. This article mainly discusses about the basics of dynamic approach of beamforming formation which will help in real-time wireless communications systems to achieve higher data-rate with higher number of users in future wireless systems. This article provides the basic context of beamforming in current systems followed by a case study. In the later part, it briefly explains about co-ordination of beamformers and its advantages and disadvantages over present systems.

Keywords— Adaptive beamforming, adaptive precoding, MU-MIMO precoder, LTE, 5G

Author:
Manuj Khanra,
Engineer,
Technology and Solutions
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Introduction

With the advancement of wireless communications, users are demanding higher data rates with lower latency. Multiple-Input Multiple-Output (MIMO) plays a crucial role in meeting such demands. [1][2] Beamforming is a technique in MIMO which lets the transmitter send data to a respective user, among many, by exploiting the channel. [3][4]

Consider a phone conference scenario, where nine people are listening to a speaker. Here, the speaker is the MIMO transmitter while the others are users (or receivers). Now say, the speaker wants to speak to the 4th person only. What can the speaker do? He can either call the 4th person directly or mute/hold the other lines. This, in wireless communications is called Transmitter Beamforming (T-BF).

In another instance, only the ninth person wants to hear the speaker and others are bored. So, they can simply put the receiver down or mute the speaker. This type of scenario is termed as Receiver Beamforming (R-BF).

There are several strategies which can be obtained to attain T-BF and R-BF. Since this article mainly discusses transmitter beamforming, it will be referred to as Beamforming (BF) throughout.

Readers may ask: What is the use of adaptive beamforming as codebook based beamforming already exists? I believe, codebook based beamforming has limited set of values therefore performance can be poorer for certain channels in certain time slot. To improve the performance in every step, the codebook values need to be updated to the make the beam formation adaptive.
Basics of MIMO

Among the different configurations of antenna systems, the systems with multiple antennas both at transmitter and receiver end, i.e. MIMO, has dominated the wireless sector with its three exceptional qualities, i.e. diversity, higher throughput, and support of multiple users. A basic block diagram of the transmitter has been shown in Figure 1 as outlined by a regulatory body - 3GPP. [5]
Context of Beamforming and Precoding

Beam is an accumulation of information generated from an antenna. It can be omni-directional or highly directive. Before setting the context, one thing should be cleared; anything that will be discussed further will be based on virtual antenna and thus will take place mostly at baseband side signal processing.

Most of the information is carried by the main lobe of the beamformed signal while side-lobes are interference as known from RF antenna beamforming. We will use that analogy to understand why we need it in baseband side and how it is done.

In RF beamforming, say an antenna forms an omni-directional beam. The same antenna can form directional main lobe beam for a particular receiving antenna while trying to nullify the side-lobe beam formation. This type of beamforming is called as directional beamforming as shown in Figure 2.
There are other types of beamforming though it is not of interest in the present context. For further understanding on beamforming please check the reference section. [6][7]

Similarly, at baseband side, the main goal of receiver is to obtain an interference free signal. Therefore, the trick is to pre-process the signal even before sending which is termed as precoding. It does almost the same job of beamformer in RF, which is why we can now refer the Beamforming as Precoding. Precoding can also be said as channel equalizer at the transmitter side.

To make this happen, channel state information (CSI) must be available at the transmitter. CSI can be complete or partial. Practically it is not possible to have the complete channel information at the transmitter, as the uplink bandwidth from receiver is limited. And thus, codebook based precoding, after severe testing, was standardized by 3GPP which gives approximately the best index among the codebook suitable for certain channel conditions.

Figure 3 shows how single-user single layer and multi-user dual layer/single layer can look like.
Interference Coordination Precoding for Multi-Cell

When we look at 5G communications, it will contain heterogeneous networks and multiple cells. This means higher interference. Thus, eNodeBs need to co-ordinate with the MSs of other cells to calculate the SINR at BS and can decide among them which users they want to serve. For this case, channel should be known to the eNodeBs for its respective UEs and also they should know the channel of other cells to co-ordinate the scheduling. As said before, channel information will be shared among all the eNodeBs and each UE will provide their interference weights to their respective connected eNodeBs and again it will be shared to manage the interference among eNodeBs to provide best eNodeB to serve the corresponding UEs. All these are a part of optimization and scheduling of users as well. As an advantage, it can provide higher data rate with coordinated interference management but as a disadvantage it will require rigorous calculations.

As pointed out previously, CSI is the most crucial factor in designing optimal precoder for wireless systems. So, feeding back proper CSI to the transmitter is still not crystal clear. Though one may look into these for general information on how partial CSI can help designing a precoder. [8][9]

In 5G, the presence of heterogeneous networks will need coordination of several eNodeBs to satisfy the needs of user. To make that happen, adaptive beamforming is only a part of 5G which can help to fulfil the demands of users.
The telecom sector depends on the demands of its users. In the early days of the GSM and CDMA market in India, companies like BSNL, Airtel, Vodafone (previously Hutchison Essar) were the biggest players. When 3G emerged, Airtel and Vodafone took over the maximum market because of the fulfilment of user demands by providing higher uninterrupted data service.

While 4G hit the market, only few telecom sectors have been able to cope with the services. Users are demanding higher data-rate and lower latency for high-end services like HD video streaming, HD video conference, cloud processing etc. To meet these criteria, 5G needs to enter the market. It will have a more efficient and faster way of communication and will also support its previous generations.

With 5G, the coverage, data-rate will increase which will help several sectors like cloud computing, D2D, Het-nets, femto and pico cells, Satcom, big data analytics, unlicensed private networks, etc. to flourish.

Sasken has already taken an initiative to build the physical and link layer for LTE-A followed by 5G.
Conclusion

With this brief on adaptive beamforming, it can be concluded, that to implement a practical system is never easy but in future, hopefully a case study will emerge based on the actual working link including the specifications by 3GPP with adaptive beamforming and channel coding. One may refer to transmission modes of LTE as specified by 3GPP for further knowledge on how this kind of system works and what are the specific requirements to be fulfilled.
References


About The Author

Manuj Khanra has been working on physical and link layer of wireless communications as a Senior Engineer in Sasken. His areas of interests are MIMO-OFDM, modulation techniques, precoding, vector quantization, visible light communications, ACO/DCO-OFDM.
About Sasken

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marketing@sasken.com | www.sasken.com

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