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ANALYSIS AND BENEFITS OF MASSIVE MIMO DEPLOYMENT AND ITS MITIGATING EFFECTS OVER DATA RATE AND RADIO LINK RELIABILITY

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Abstract

Massive Multiple Input-Multiple Output (MIMO) is the most versatile network with adequate wireless access and technological capabilities to achieve bandwidth gain without increasing latency. MIMO remains a digital platform for fifth generation (5G) operations. Its techniques in radio communication systems have helped to massively deploy multiple antennas technology in enhancing effective and accelerated channel capacity utilization. The research focused on massive MIMO deployment models and its mitigating effects over data rate and radio link reliability. In a MIMO system, same data is transmitted through multiple antennas over the same path in the same bandwidth. There are three main categories: pre-coding, spatial multiplexing and diversity coding. Interferences in the channel vector which were not selected for transmission to be [redacted] suppressed eliminated using Zero forcing processing technique. The zero forcing beam forming receives signals from intended users and simultaneously nulls out interference from interfering users. In this study, relevant data were

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collected from base station controller and network mobile switching centres. The data collected from a large number of smart transceiver antennas and traditional multi-access system protocols were analyzed. The simulation results of the data analysis and interpretation showed low latency, high data rate thereby increasing system reliability with robust multiplexing gain and beam forming capabilities.

Introduction

Massive MIMO is massive use of antennas to increase spectral efficiency and meet the 5G wireless mobile network requirement. Massive MIMO has the capacity to deliver data to multiple users and multiple mobile stations simultaneously while ensuring fast data rate and the performance reliability of the entire radio communication link.

These technologies rely on wireless propagation models so that performance analysis of large antenna wireless systems can be obtained using models. Massive MIMO is a predominantly 5G technology. However, there are a lot of smart phones with 4G network support such as the huawei p9 and p1 and remarkably some iphone series.

Massive MIMO is one of the key enabling technologies for on-ward evolution of new radio technology to meet the global means for spectrum and channel capacity (Almers, 2007). It is an antenna configuration technology which groups together antennas at both transmitter and the receiver. This is to provide high spectral and energy affinity using relatively simple processing techniques and can sense data from concurrent sensor transmission with much lower latency and provide sensors with higher data rates and communication link reliability (Almers, 2007)

Whereas a standard MIMO uses between 2 to 4 antennas, massive MIMO uses as much as 6 as well as 256 antennas both at the transmitter and at the receiver. A good robust knowledge of the massive MIMO phenomenon is fundamental in the successful deployment and implementation of the 5G technology in order to realize the various applications such as intelligent sensing systems.

MIMO techniques have a number of advantages such as high signal strength, data speed enhancement, latency of data across the network, enhancement and utilization of beam forming technology, flexibility of operations, high rate antenna

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spatial distribution , optimized gain in antenna propagation and Smarter implementation and enabling spectrum utilization.

Historical Development

Almers P (2007) investigated the concept and implementation of MIMO in his work on Survey of channel and radio propagation models for wireless MIMO systems, this was done by using a separate antenna for transmitting and receiving of each data signal. Typically, a standard MIMO network uses 2 to 4 antennas to transmit data and uses the same number to receive it (Almers, 2007). He concluded that MIMO technology offers a lot of gains and flexibility in the radio communication sub-sector especially in fast racking data communication and enhancing more robust live streaming data opportunities for a fast moving information and communication, ICT- driven global community.

Soysal, A. and Ulukus, S. (2007), in their research efforts in Optimum power Allocation for

Single-User MIMO and Multi-User MIMO-MAC with Partial CSI, built on this implementation by up scaling the developed MIMO technology to offer a lot more gains and flexibility in the radio communication scheme.

Dao, (2011) presented a 3D Polarized channel modeling and performance comparison of MIMO antenna configurations with different polarizations. This is implemented by using a separate antenna for transmitting and receiving of each data signal (Dao, 2011).

Ben, (2012) observed computational complexities and operational techniques challenges in his work in MIMO spectral efficiency over energy consumption requirements. according to him, MIMO consists of multiple antennas at the input and output and with MIMO techniques, the capacity of a communication system increases linearly with the number of antennas thereby increasing the spectral efficiency of the communication system without requiring increase in resources in terms of bandwidth power. As a result of the need to reduce the area for more antennas involved, MIMO techniques require the use of high frequency and shorter wave length than the conventional mobile network standard (Ben, 2012)

Typically, a standard MIMO network uses 2 to 4 antennas to transmit data and uses the same number to receive it. MIMO technology offers a lot of gains and flexibility in the radio communication sub-sector especially in fast racking data

communication and enhancing more robust live streaming data opportunities for a fast moving information and communication, ICT- driven global community. Furthermore, the multiple input/output technique is a wireless communication tool for multiplying the capacity and versatility of a radio link using multiple transmit and receive antennas to implement a propagation pattern called multipath propagation (Rusek, 2013).

It is worth mentioning here that while smart antenna concept is activated to drive the performance of a single data. MIMO technique encompasses the capabilities for sending and receiving more than one data signal over the same radio channel via the multipath propagation technique as well as accommodates programming of software solution and application packages such as java script and HTML.

MIMO interfaces with the 4G Long Term Evolution, LTE technology. The long term evolution standard in radio communication is a concept that utilizes high frequency technology to increase the speed of wireless communication for mobile services and data terminals based on the GSM, EDGE and UMTS technologies. In earlier studies and innovations, the Chinese network technological co-oporation ZTE and Huawei both announced new Europe massive MIMO tests in October 2017. Also in 2017, Vodafone and Huawei did show off massive MIMO technology. A Uk corporation also implemented massive MIMO with speed up to 2.8Gbps.

LTE increases the capacity and speed using a different radio interface together with core network improvement. The LTE is developed by the 3GPP- 3 rd Generation partnership protect and it is the upgrade path for carriers with both GSM and UMTS network (Viera, 2014).

The high speed packet access is robust digital platform that enhances and enables the Long Term Evolution, LTE to implement its high speed and capacity in wireless radio communication. The HSPAP is the second phase of HSPA where the second P signifies a plus. Multiple-input Multiple (MIMO) communication system exploits antenna arrays at both the transmitter and receiver to offer parallel sub-channels to enhance the system capacity and quality of service (QOS) without requiring additional bandwidth or carrier power. Nevertheless, realistic MIMO channels suffer from significant degradation of diversity gain and MIMO capacity due to the spatial correlation between signals at different receiving antennas. The performance of adaptation techniques such as power allocation and antenna

selection algorithms are also by the spatial properties of the multipath channels (Dao, 2011).

Spatial correlation is a measure of the similarity of signals at different antennas and it is a function of the spacing between antenna elements, radiation patterns, mutual coupling, array geometry, angular energy distribution of incoming waves, and the frequency of operation.

Lower correlation coefficients are highly desired to improve the performance of multiple antennas system in order to achieve a large diversity order, both base stations (BS) and mobile station (MS) antennas elements should be separated sufficiently.

In radio communication, multipath propagation is the phenomenon that results in radio signal reaching the receiving antennas by two or more paths. There are different causes of multipath which includes reflection from water bodies such as seas and oceans, reflection and also refraction from mountains, rocks, platues, high rise buildings and similar terrestrial bodies.

The causes of multipath propagation are constructive and destructive interference. Another cause is a shift in phase of the signal. Destructive interference causes fading where the strength of the signals arriving by the various paths have a distance known as Raleigh fading. Another type of fading is the Rician fading where one component dominates and the distance provides a more accurate model.

The communication channel represent a major component that determine system performance. Modeling of channels is essential for the design of wireless systems. The need to improve capacity, increase spectral efficiency and minimize the effect of multipath interference has resulted in multiple antennas system at both ends of communication link otherwise known as multiple-input-multiple-output (MIM O) system (Gao, 2015).

The MIMO system operates at a level of complexity that exploit channels space-time resources required to access the potential performance of practical multi-antenna links. In a MIMO wireless system, the transmitted signal interacts with the environment in a very complex way.

This is as a result of reflection, diffraction and signal scattering resulting from object/scatterers in the signal path and electromagnetic wave around objects. A continuous succession of paths is produced by each scatterer joining the

transmitter and receiver. Thus, a channel model for non line of sight (NLOS) propagation must involve details about the multipath environment, the communication link can be described by properties such as amplitude face variation, carrier phase; time delay spread information, power delay profile, angle of arrival and departure, Doppler shift and the number of multipath components. MIMO technique uses multi-path propagation to get multiple independent channels. Multi-path interference is a phenomenon in multi-path propagation in which a wave from a source travels through two or move paths and the two elements or components of the wave interference, thereby resulting in fading of radio waves (Raoof, 2009).

In the propagation condition, co-herent waves that travel along two different paths will arrive with phase shift thereby interfering with each other. Interference is a phenomenon in which two waves superpose to form a resultant wave of greater, the same or even lower amplitude.

Interference depicts interaction of co-herent or correlated waves of the same or close frequency and the same source.

This can also be observed, with all types of waves including acoustic, surface-water waves, light or most significantly in radio waves. Radio waves are a type of electro-magnetic radiation with wavelength in the electro-magnetic spectrum longer than infared light. Radio waves have frequencies as high as 300 GHz to as low as 30 Hz. Radio waves travel at the speed of light. They are generated by electric charges, undergoing acceleration such as time varying electric current. Radio waves are generated by transmitters and received by radio receives using antennas. Radio waves are largely used in radio communication, broadcasting, radar technology, communication satellite, wireless communication, etc.

In communication systems, antenna arrangement and configuration is networked and optimized using the MIMO techniques to enhance greater channel propagation and signal quality.

Beam forming

Beam forming is the capacity of the base station to adapt the radiation pattern of the antenna. Beam forming helps the base station to find a suitable route to deliver data to the user. It also reduces interference with nearby users along the route. Beam forming has several advantages for

5G and 6G networks.

Depending upon the circumstance, beam forming can be implemented in several different ways in 5G networks and beyond. For massive MIMO systems beam forming helps in boosting data rates. In massive MIMO systems, the base station can send data to the user from various paths and beam forming then appropriates the packet movement and arrival time to allow more users to send data simultaneously (Soyal, 2007).

In case the millimeter waves cannot penetrate through obstacles and do not propagate to longer distances to shorter wavelength, beam forming then helps to send concentrate beams towards the users. This beam forming helps the user to receive a strong signal without interference with other channels. MIMO systems are an integral part of current wireless systems and they are highly instrumental to achieving high spectral and energy efficiency (Vieira, 2014).

As a result of the versatility associated with the exploration of new age technologies and applications, it is imperative that higher capacities be developed in this regard to handle the magnitude and the volume of data traffic with more speed and channel link reliability which the 4G and the Long Term Evolution technologies cannot handle. Therefore the deployment of 5G which is highly enabled by the MIMO technology is helping a lot to manage these capacities.

Massive MIMO is the most enhanced technology for 5G, 6G and going forward for the wireless era. Massive MIMO is the advancement of conventional MIMO systems used in current wireless networks which groups together hundreds and even thousand of antennas at the base station and serves tens of users simultaneously. The extra antennas that massive MIMO uses helps you focus and direct energy into a smaller region of space to provide better spectral efficiency and throughput.

Massive MIMO downlink and the uplink are usually taken into cognizance. As the number of antenna increases in a massive MIMO system, radiated beams become narrower and spatially focused toward the user. The beam pattern for different antenna configuration is also highly noted. These spatially focused antenna beams increase the throughput for the desired user and reduce the interference to the neighboring user. Massive MIMO offers a great deal of advantages over the traditional MIMO systems (Gao, 2015).

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Uplink Transmission

The uplink channel is used to transmit data and the pilot signal from the user terminal to the base station. A massive MIMO engages uplink system with antennas at the base station and simultaneously communicates the single antenna user where the base station antenna is larger than the user antennas.

Downlink Transmission

The downlink channel is used to transmit data or estimate the channel between the user and base station. The base station uses training pilots to estimate the channel between user and base station. The base station uses training pilots to estimate the channel.

Benefits of Massive MIMO For 5G And 6G Networks

1. Increased Data Rate – The array of gain and high multiplexing provided by massive MIMO increases the data rate of wireless systems.
2. Increased Channel Capacity- massive MIMO antenna configuration systems usually increase system channel capacity.
3. Increased Spectral Efficiency- massive MIMO provides increased spectral efficiency by allowing its antenna array to focus narrow beams towards a user. With massive MIMO, exponential gain can be achieved over traditional MIMO systems such as in 4G/LTE systems.
4. Low Power Consumption- massive MIMO is usually designed with ultra lower linear amplifiers which go a long way to simplifying the equipment components and reduces power consumption effectively.
5. Increased Energy Efficiency- Energy efficiency can be greatly enhanced when the antenna array is focused in a particular area which will require less radiated power and reduces the energy requirement in the systems.
6. Less Fading- A large number of antennas at the receiver makes massive MIMO mitigates fading effects.
7. User Tracking- As a result of the narrow signal beams toward the user as required in this system, user tracker can be readily achieved with a high level of precision and accuracy.
8. Robustness- These systems are robust against interference.
9. Low rate of antenna failure- Also as a result of the large number of antennas involved in massive MIMO, the rate of antenna failure is very low thereby making the entire system more reliable.

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10. Increased Reliability- A large number of antennas in massive MIMO provides more diversity gain. This characteristic increases the link reliability.
11. Low latency- The air interface latency is reduced.
12. Low Complex Linear Processing- The more the number of base stations as it is in massive MIMO systems, the more the signal detectors and the pre-coders function optimally.
13. Security- Due to the orthogonal mobile station channels and narrow beams, massive MIMO systems are more security enhanced.

The MIMO Technology Enhancement of Mobile Communication Exponential Transformation

Telecommunication has evolved significantly over the past decades ranging from the first generation analog networks through the second generation global system for mobile communication 2G. The advancement progresses to the more advanced code division multiple access 3G and recently the highly enabled 4G networks currently being exploited in most countries across the world. Then came the most intriguing and exceptional 5G network for the future exploration.

However social and economic activities continue to thrive especially on the robust platform of mobile telecommunication especially the evolution of the 4G enabled Long Term Evolution, LTE. This trend has empowered and equiped the users to activate mobile power opportunity in their daily lives. This includes audio calls, text messages, short message services, medium message service, video calls, video services, social media applications, webchats, Facebook, twitters, high data rate, low latency, e.t.c. (Rusek, 2013).

The advancement in mobile communication has been projected to penetrate every aspect and fabric of our daily lives while also creating all dimensional, user-centered information ecosystem for unlimited economic gains. The growth of data traffic creates increase in device in connection with emergence of new services (Ben, 2012).

The explosive growth of Multiple Input Multiple Output systems has permitted for high data rate and a wide variety of applications. Some of the technologies which rely on these systems are IEEE 802.11, Third Generation (3G) and Long Term Evolution (LTE) ones. Recent advances in wireless communication systems have

contributed to the design of multi-user scenarios with MIMO communication (Rusek, 2013).

These communication systems are referred as multi-user MIMOs. Such systems are intended for the development of new generations of wireless mobile radio systems for future cellular radio standards. This provides an insight into multi-user MIMO systems.

MIMO Enhancement of 5G Mobile Communication Network

As a means of driving the mobile communication technologies, the mobile and wireless communications enablers 2020 information society project of European Union started research work of 5G at the end of 2012. In China, IMT-2020 promotion group served as a platform to promote the 5G study.

In South Korea, Samsung tested and verified the technical feasibility of milestone of millimeter wave in the bands of about 28GHz. Other technologies that have emerged include MIMO and new channel coding (Vieria, 2014).

These have all taken a pivotal space in the world of research and development for actualizing global commerce and trade for the benefit of man. The capabilities of 5G technology is ubiquitous and it is precipitated upon a sustainable ecosystem of mobile communication system as a result of the global network coverage, it has the capabilities to meet the market demand for global economic recovery.

5G network holds a variety of advantages over the earlier technologies such as 4G, 3G, 2G and the first generation analog technology. The 5G advantages include highly enhanced data speed, file transfer volume and speed, tremendous amount of growth in connectivity, much broader usage and other possibilities above 4 G networks (Gao,2015).

As a matter of more advances in research and development, 6G technology is already being explored and studied in China. It is hoped that when fully developed 6G technology will be deployed for its vast benefits for man. This will further impact the much desired sustainable economic global recovery.

MIMO Information Theory in Channel Allocation

Having introduced the basic concepts of MIMO communication as well as MIMO channel fundamentals and system performances, then, we can now concentrate our analysis on the multi-user MIMO systems and provide a conceptual

understanding with the multi-user MIMO technology. To do so, we present the communication system model for such emerging technology and give some examples which describe the recent advances for multi-user MIMO systems.

This is the channel model for developing signal processing algorithm which describes the radio channel by the correlation between the different links established between individual antenna elements hence making the model mathematically viable. Also there is channel model for MIMO deployment in a given environment (Vieira, 2014).

Furthermore, there is also deployment of channel models for testing of algorithm and systems. A time variant channel is essential feature of mobile communication. For instance, the 3GPP spatial channel model which is also suitable for simulating random access communication. The channel also encompasses Doppler fading but after a drop the channel changes completely.

Channel Allocation Algorithm Models For 5G Massive MIMO Systems.

A wireless dynamic channel allocation algorithm for HAPS 5G massive MIMO communication based on distance decision is proposed, which guarantees the quality of service of all kinds of services and maximizes the resource utilization ratio of high-altitude platform communication in reference. Aiming at solving the problem of horizontal swing caused by a stratospheric crosswind on high-altitude platforms, a channel allocation algorithm combining channel reservation with handoff queuing is proposed to solve the problem of handoff between cellular for the ground calling users to continue to obtain reliable services (Gao, 2015).

The algorithm takes full account of the service level requirements of different types of user terminals, differentiates the priority of user terminals, and queues the handoff callers on the basis of channel reservation from the viewpoint of reducing the handover failure rate. The HAPS 5G massive MIMO network encounters a large number of data connections and the channel allocation that needs to be processed will be massive, while the HAPS 5G massive MIMO network is an autonomous learning and self-renewal intelligent system for the unknown environment, which can sense the external environment and learn from the environment by using artificial intelligence technology.

By changing some operating parameters (such as transmission power, carrier frequency, and modulation technology) in real time, it can adapt to the statistical

characteristics of the received wireless signals, so as to realize reliable communication and efficient utilization of spectrum resources anytime and anywhere. Therefore, this study proposes an intelligent wireless channel allocation algorithm for 5G massive MIMO communication system based on reinforcement learning, which adopts learning reinforcement algorithm in artificial intelligence.

Conclusion

Results of experimental values of MIMO channel measurements was performed in a real scenario under both line of sight LOS and non line of sight non LOS conditions at the 900MHz in the urban environment. A channel system based on a software defined ratio SDR platform was implemented and used to perform various levels of communication and radio frequency validations were carried out using various equipments platforms such as signal generators, vector network analyzers and spectrum analyzers. SDR provides a cost effective and flexible measurement set up and implemented with software that enabled the use and control of the radio signal through software MATLAB and other software tools.

This is done by increasing the spectral efficiency of the MIMO system at an expense of increased transmitter and receiver complexity while the errors are minimized .It is noteworthy to mention that the fixed number of transmitters also influence in predetermining the fading process to be non selective. Another notable observation is that channel gains are independent slowly varying complex Guassian variables. Finally, it is also observed that channel gains are usually associated with the error messages.

In this work, the second order statistics of the measured parameters have been derived with standard proactive and reactive relaying schemes. It is shown that the theoretically derived parameters performances match the simulated results.

References

Almers, P., Bonek, E., Burr, A., Czink, N.and Debbah, M.(2007). Survey of channel and radio propagation models for wireless MIMO systems, EURASIP Journal on Wireless Communications and Networking Vol. 2007(No. 1): 1–19.

Ben Zid, M., Raoof, K. and Bouallègue, A. (2012). MIMO spectral efficiency over energy consumption requirements: Application to WSNs, Int'l J. of Communications, Network and System Sciences Vol. 5(No. 2): 121–129.

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Prof. Saeid Eslamian [IRAN]

Ben Zid, M., Raoof, K. and Bouallègue, A. (2012). MIMO Systems and Cooperative Networks Performances, in: Advanced Cognitive Radio Network, Scientific Research Publishing, ISBN: 193–506–874–1.

Dao, M.T., Nguyen, V.A., Im, Y.T., Park, S.O. & Yoon,G.(2011). 3D Polarized channel modeling and performance comparison of MIMO antenna configurations with different polarizations, IEEE Transactions on Antennas and Propagation Vol. 59(No. 7): 2672–2682.

Gao X, Edfors O, Tufvesson F, Larsson E G (2015). Multi-Switch for Antenna Selection in Massive MIMO IEEE Global Communication Conference (GLOBECOM), San Diego, California, USA. pp12-10.

Raoof, K. and Zhou, H. (2009). Advanced MIMO systems, Scientific Research Publishing, ISBN:978–1–935068–02–0.]

Rusek F, Persson D, Lau B. K,Larsson E. G, Marzetta T. L,Edfors O,Tufvesson F (2013). Scaling up MIMO: opportunities and challenges with very large arrays IEEE Signal Processing Magazine, Vol. 30, No. 1, pp. 45-55.

Soysal, A. and Ulukus, S. (2007). Optimum power Allocation for Single-User MIMO and Multi-User MIMO-MAC with Partial CSI, IEEE Transactions on Selected Areas in Communications Vol. 25(No. 7): 1402–1412.

Vieira J,Malkowsky S, Karl F. N, Zachary M, Nikhil K, Liang L, Ian C. W, Viktor Ö, Ove E, Fredrik T (2014). A flexible 100-antenna testbed for Massive MIMO IEEE GLOBECOM 2014 Workshop on Massive MIMO: From Theory to Practice, Austin, Texas, U.S.A.,

Vieria J, Rusek F, Tufvesson F (2014). Reciprocity calibration methods for Massive MIMO IEEE GLOBECOM 2014, Austin, Texas, U.S.A., 2014-12-08/2014-12-12.

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