Journal of Software Engineering

ISSN 1819-4311

Academic
Journals Inc.

www.academicjournals.com

OPEN ACCESS Journal of Software Engineering

ISSN 1819-4311
DOI: 10.3923/jse.2017.275.281

Research Article
A Dynamic Energy Economy for Green Communication Using Multiple Input Multiple Output

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Abstract

Background: Communication has become an integral part of people lives and like any innovation, it faces the problem of energy efficiency due to new technologies and the number of growing users. Hence, initiatives are being taken to find solutions to this problem and to attain green communication which reduces the energy consumption and should not compromise on the Quality of Service (QoS). With the phenomenal increase in the number of users using cellular devices, it now becomes important to knock at green communication. **Materials and Methods:** In this study, an idea to bring out what green communication exactly aims at in the context of wireless communication and give an overview of the various approaches followed in implementation of green communication with emphasis on cognitive radio mechanism. It also focuses on the concept of Multiple Input Multiple Output (MIMO) technique that can be used in developing technologies and proves to be beneficial when compared to Single Input Single Output (SISO) or Multiple Input Single Output (MISO) when taking into consideration the energy efficiency of the system. **Results:** Comparison of different transmission models based on their BER, distance and energy consumption per bit were estimates. This simulation shows that the BER of MIMO is better than the other schemes and also the performance of MISO and SISO are comparable to each other. Bit Error Rate (BER) of MISO and SISO increases with distance, while that of MIMO remains relatively constant. A similar result is obtained when the energy consumption per bit is plotted with distance. From aforementioned simulation result, it can infer that MIMO proves to be advantageous with increasing the distance and that in some cases MISO performs better than SISO. **Conclusion:** This simulation gives the comparison based on the total energy consumption per bit, which includes the circuit power consumption of the transmitter and receiver. This simulation clearly shows that MIMO concept should be used when the distance used is longer.

Key words: Green communication, cognitive radio, MIMO, QOS, BPSK, AWGN, femto cell, BER

Received: December 03, 2016 Accepted: March 29, 2017 Published: June 15, 2017

Citation: K. Revathy, K. Thenmozhi, Padmapriya Praveenkumar and Rengarajan Amirtharajan, 2017. A dynamic energy economy for green communication using Multiple Input Multiple Output. J. Software Eng., 11: 275-281.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The Information and Communication Technology (ICT) industry has taken a major shift in the past few years with the advent of smart phones and with social media getting on to the next level. The number of users using the telecom spectrum has increased magnanimously owing to these changes. This now puts pressure on the network operators to increase their coverage area till the last mile, which indirectly means that they will now have to establish more base stations which ultimately results in excess use of energy both by the service provider and the end user. With the atmospheric CO_2 levels raging to alarming levels, it becomes necessary in increasing the efficiency of the service providing stations in terms of energy. This is where, the concept of green communication, comes into the picture[1,2].

Green communication does not directly aim at reducing the CO_2 levels, rather aims at increasing the energy efficiency of the mechanism through which the spectrum is brought to the user's disposal and analysis the overall end to end system efficiency[3-5]. Escalating energy costs and the future uncertainty of the availability of fossil fuels have made researchers to focus on achieving 'Greener' communication technologies. With technological advances and communication becoming ubiquitous, user expectations have grown[2,6-9]. Hence, it becomes impossible to ignore the carbon footprint left by communication systems, especially wireless communication. Green communication aims to make the cellular networks energy efficient while maintaining its profitability[10-12]. Over the years many techniques have been developed to assist in communication and to efficiently utilize the available resources like the spectrum[13-18].

In wireless communication systems, multipath propagation is prevalent and communication technologies have to be able to handle this phenomenon one way or another. The cellular network sector has expanded rapidly due to the increase in the number of mobile subscribers, multimedia applications and data rates. Consequently the number of base stations has increased and will further rise in the future to adapt to the changing environment. This leads to a higher energy consumption which indirectly affects green house gas emissions and also has an impact on operational expenditures. Multipath propagation is caused because of the different existing paths between a transmitter and receiver. These paths may be the result of atmospheric dusting, ionospheric reflection and refraction and reflections from obstacles like buildings and mountain, reflective surfaces, etc., that may be adjacent or along the main path.

Distortion of the transmitted signal, loss of data and multipath fading are some of the consequences of multipath fading, but MIMO concept uses multipath propagation to advantage and increases the capacity of the channels. Multiple antennas are known to improve performance through spatial diversity or by increasing data rates by spatial multiplexing. Apart from MIMO and SISO, other schemes such as Multiple Input Single Output (MISO) systems are also available which as the name suggests has multiple transmit antennas but a single receive antenna. Each transmission scheme has its own advantages.

Energy consumption can be minimized and simultaneously given throughput and delay requirements can be satisfied. At the same transmission power and Bit Error Rate (BER) requirements, MIMO systems have been observed to require less transmission energy. The total energy consumption is the addition of transmission energy and the energy intake of circuit components of the antennas. Hence, both transmission energy and circuit energy consumption must be taken into consideration for the analysis of energy efficiency.

This study aims to achieve energy efficiency by focusing on the transmission scheme of a communication system using MIMO concept. Also an overview of various approaches in establishing green communication adopting cognitive radio concept is also incorporated in this study. A MIMO system utilizes multiple antennas at the ends of the communication link, contrary to the SISO system which is usually used. These systems have been studied intensively over the years. Even under conditions of interference, signal fading and multipath, MIMO systems offer enhanced data throughput and efficiency. Here 3 transmission schemes like MIMO, SISO and MISO has been designed, considering the energy consumption involving throughput and BER requirements. Binary Phase Shift Keying (BPSK) based systems and alamouti diversity codes were used in MIMO and MISO simulations and the energy efficiency of these systems were compared over different transmission distances.

MATERIALS AND METHODS

System model: A simple communication link between 2 nodes has been considered. The MIMO, SISO and MISO systems are simulated. The transmission scheme adopts Binary Phase Shift Keying (BPSK). Initially, a SISO system is modelled assuming a flat Rayleigh fading channel, hence the channel matrix is a scalar. Then the transmitted data is multiplied with the channel matrix and Additive White Gaussian Noise (AWGN) is added to it.

$$Y = Hs+N \tag{1}$$

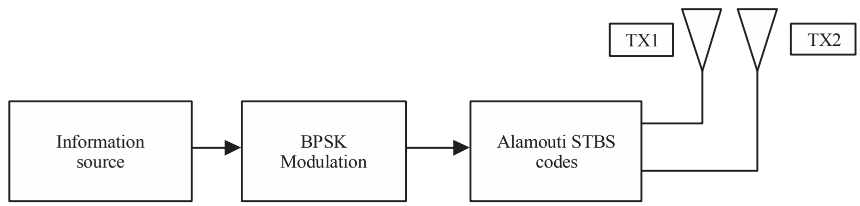

Fig. 1: Block diagram of the proposed model

At the receiver end hard decision decoding is done to estimate the transmitted data.

For MISO and MIMO, Alamouti Space Time Block Codes (STBC) is used. In space-time block coding, multiple copies of data are transmitted across the antennas. The transmitted signal usually travels through an environment that causes significant scattering, reflection and refraction. These phenomena results in redundancy of data and the various received versions are relied upon to correctly decode the signal. Space-time coding combines different copies of a received signal and extracts information from them as shown in Fig. 1.

In the alamouti scheme, the symbols are first divided into sets, where the number of symbols or data equals to the number of transmitters. In the first time slot, the symbols are transmitted by allotting each symbol in a particular set to an antenna. In the second time slot, the conjugate of the symbols are sent and in a different order such that the code matrix is orthogonal and the rows and columns are also orthogonal. Equation 2 and 3 represent the way in which symbols are transmitted by the two transmitters:

$$TX^1 = [S_1\text{-}S_2^*] \quad (2)$$

$$TX^2 = [S_2\ S_1^*] \quad (3)$$

where, S_1 and S_2 are two consecutive symbols which need to be transmitted. Using the above models, about 1000-10000 randomly generated samples are evaluated and their Bit Error Rates (BER) is obtained at each transmission distance. From this the required energy per bit is calculated for the desired BER which is calculated using the Chernoff Bound which provides the upper bound for the required energy per bit by using Eq. 4:

$$Eb \leq \frac{MtNo}{Pb^{\left(\frac{1}{Mt}\right)}} \quad (4)$$

where, Mt is the number of transmit antennas.

The power consumption of the power amplifier depends on the transmit power P_o and is calculated using the link budget relationship as shown in Eq. 5:

$$P_o = EbRb \times \frac{(4\pi d)^2}{GtGr\lambda^2} \times M_l N_f \quad (5)$$

where, Rb is the data rate, d is the transmission distance, Gt and Gr are the antenna gains of the transmitter and receiver respectively, λ is the carrier wavelength, M_l and N_f are the link margin the noise figure. The energy consumption per bit when not considering the circuit power consumption can be given by using Eq. 6:

$$E_{bt} = (1+\alpha) \times P_o/Rb \quad (6)$$

where, α depends on the drain efficiency of the RF amplifier and Peak-to-Average Ratio (PAR).

However, to accurately compare the energy efficiency of the different transmission schemes, it should also include the energy consumed by the circuit components. The circuit power consumption is calculated by considering the power consumed by the transmitter and receiver during the transmission process. Equation 7 which approximately gives the above stated parameter is:

$$P_c \approx Mt(P_{dac}+P_{mix}+P_{fil})+2P_{syn}+Mr(P_{lna}+P_{mix}+P_{ifa}+P_{fil}+P_{adc}) \quad (7)$$

Hence, the total energy consumption for the transmission can be given by using Eq. 8:

$$E_{bt} \approx (1+\alpha) \times P_o/Rb+P_c/Rb \quad (8)$$

RESULTS AND DISCUSSION

Comparison of different transmission models based on their BER, distance and energy consumption per bit were estimates. Figure 2 evidently shows that the BER of MIMO is better than the other schemes and also the performance of

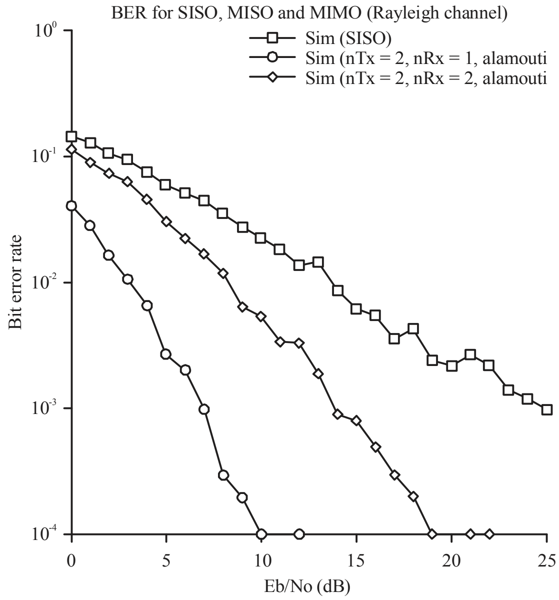

Fig. 2: Comparison of BER for the transmission schemes with Eb/No

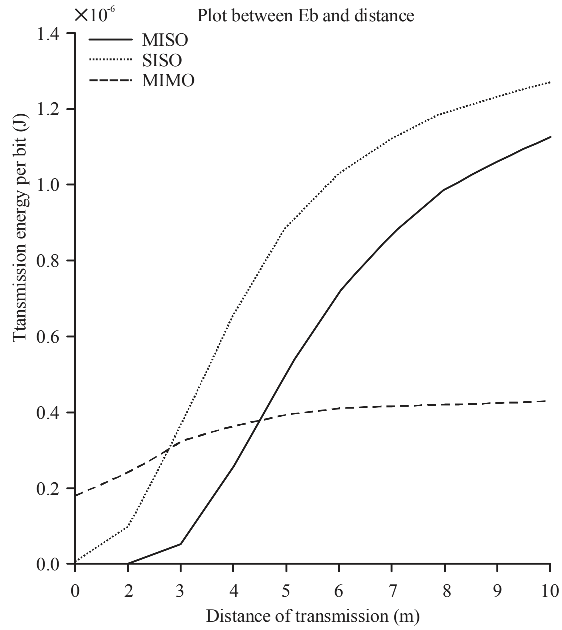

Fig. 4: E_b vs. distance for MIMO, SISO and MISO

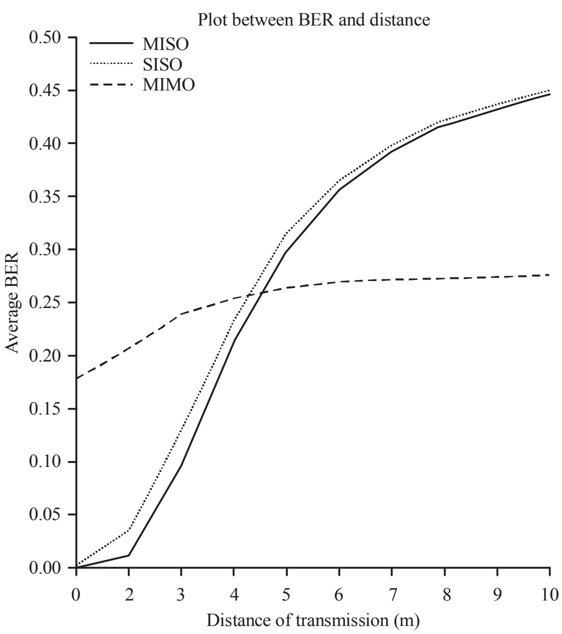

Fig. 3: BER vs. distance for MIMO, SISO and MISO

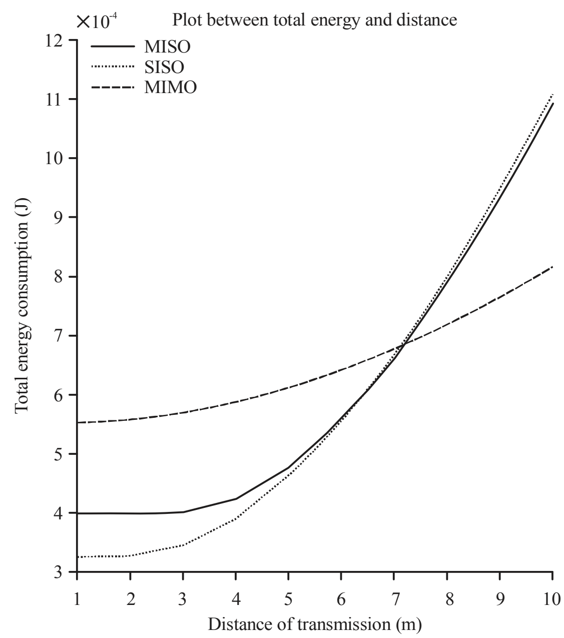

Fig. 5: Total energy consumption vs. distance for MISO, MIMO and SISO

MISO and SISO are comparable to each other. The BER of MISO and SISO increases with distance, while that of MIMO remains relatively constant as shown in Fig. 3. A similar result is obtained when the energy consumption per bit is plotted with distance as in Fig. 4. From Fig. 3 and 4, it can be inferred that MIMO proves to be advantageous with increasing the distance and that in some cases MISO performs better than SISO. Figure 5 gives the comparison based on the total energy consumption per bit, i.e., it includes the circuit power consumption of the transmitter and receiver. The plot clearly shows that MIMO concept should be used when the distance used is longer.

In recent times Cooperative Cognitive Radio Networks (CCRNs) sets a new trend of cognitive communication between Primary Users (PUs) and Secondary Users (SUs) in a

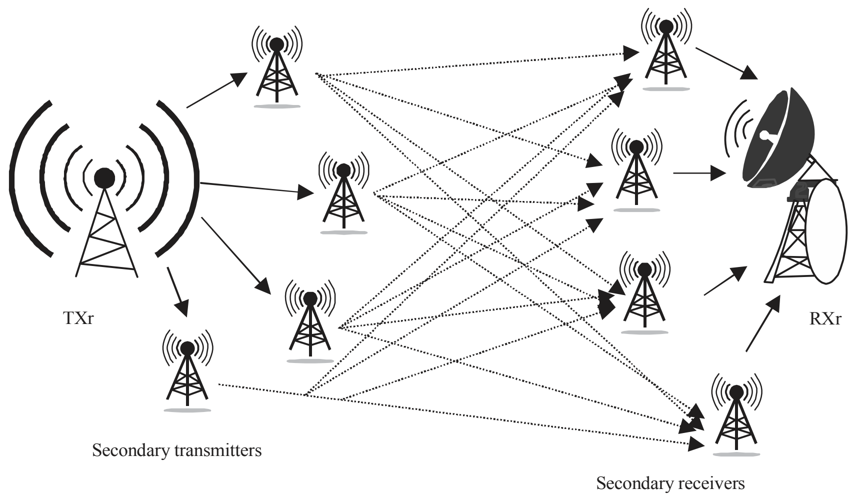

Fig. 6: MIMO in CR networks

cooperative manner[17,18]. In this study, significance of MIMO concept has been utilized for several data transmission thereby improving the gain performance of the CR system as compared with single antenna based system[17].

Figure 6 provides the usage of MIMO concept in CRN, to enhance the sensing and to improve the throughput of the system. The system consists of a primary transmitter and a receiver unit. The primary transmitter transmits the data to the secondary transmitters where it will be distributed to the secondary users using MIMO concept, the same concept has been carried at the receiver end also[17]. This avoids the overload problem with primary user and always a win condition with secondary user in utilizing the spectrum.

Overview of approaches in establishing green communication

Green metrics: There are several metrics to measure the greenness, however, there are two most important metrics of all, namely Energy Consumption Rating (ECR) and Energy Consumption Gain (ECG). The ECR is a simple metric which is the ratio of peak power required in the transmission to the maximum data throughput achieved by the transmitter at base station. This is an absolute metric which is expressed in micro joules per bit. Energy Consumption Gain (ECG) on the other hand is given by the ratio of energy utilization by baseline transmitter to the energy utilized by system under test. The larger the value of the system under test, greater is its efficiency.

Approaches for green communication: Various approaches followed in green communication mainly focus on improving the energy efficiency contributing towards greenness.

Improving efficiency of base station: With an unprecedented increase in the number of users accessing the cellular networks, the need for increased base stations has become inevitable and has grown up exponentially over the years. Also, the existing base stations will now have to use more power as they have to increase their area of coverage. It is estimated that the power requirement of each base station may escalate up to as high as 1400 W leaving a carbon foot print of about 11 t equivalent of CO_2.

Power amplifiers account for about 40% of the energy consumed by the base station, but the efficiency of these power amplifiers is just around 5-20% which is very poor. To some extent this problem can be solved by using Gallium Nitride Amplifiers or Doherty Power Amplifiers.

Using renewable power generation mechanism for generating the energy required to run the base stations as suggested by GSMA, seems to be another viable option. With the renewable energy sector improving each day at a rapid pace this is may turn out to be an interesting choice.

Cognitive radio mechanism: Green communication can be enhanced by efficient utilization of the spectral resources and this is what exactly can be done by using the cognitive radio.

Cognitive Radio (CR) is an intelligent mechanism which has the property of cognition to its surroundings, which can dynamically sense the spectrum to find if the spectrum is completely occupied or has some vacancies called spectrum holes. These holes once found out will be assigned to a secondary user who does not have license thus improving the spectral occupancy and efficiency. Cognitive radio itself is a complex mechanism with several tasks to be carried out.

It is imperative that better efficiency is possible with CR only when the CR itself is efficient. How do we achieve this is another question here. As mentioned earlier the CR is cognitive, it detects the number of available channels at any moment and selects a modulation index and modulation order as to suit the demands like QoS and required BER. Detecting the number of available channels is a major factor. With rapid development in artificial intelligence and cutting edge digital signal possessing techniques it is expected that CR technology becomes a major approach in green communication in the future.

Cross layer techniques: Most of the mobile communication devices follow the OSI layer architecture, wherein the tasks to be performed are divided into layers which are used to carry out a specific task set to them and these layers are independent from each other. A cross layer design scheme can be implemented in such cases which essentially is a mechanism in which the unnecessary layers and functions can be removed and other layers can be assigned tasks if required. Also several strategies independent to each of the layers can be applied in order to lower the power consumption while maintaining the QoS and bit rate requirement.

Network deployment: Base station requires more power to transmit signal to mobile stations which are far from it. At the same time we need larger cells to be able to cover wide areas. This imposes a problem on the base station requiring it to dissipate more power. One way to overcome this drawback is to opt for heterogeneous networks.

The idea behind heterogeneous networks is cell zooming in which the larger cells often called macro cells are divided into smaller micro cells or pico cells so that one larger base station will be divided into a number of smaller base stations there by reducing the load on larger base station.

Femto cell mechanism is a very similar approach which aims to reduce the power consumption in mobile networks and can be seriously considered for faster and efficient transmission of data in indoor environments. It is evident that 60% efficiency can be achieved using micro cells when compared to the energy consumption with macro cells.

CONCLUSION

Green communication has become the need of the hour and MIMO scheme can prove to be a boon for achieving energy efficiency without compromising on the quality of service, with increasing distance. But for shorter distances MISO or SISO can be used. Although SISO is preferred because of the comparable results and also due to the fact that the circuit energy consumption plays a significant role when considering short distances. The MIMO can be adapted to most of the developing technologies like the cognitive radio, the most needed technology to cater to the ever growing user demands.

SIGNIFICANCE STATEMENTS

- Overview of various approaches in establishing green communication
- Implementation of green communication using MIMO concept
- BPSK based alamouti diversity codes were employed in analyzing the BER of the proposed scheme

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