How to Cite:
Shitiz Upreti and Dr. Mahaveer Singh Naruka (Dec 2017) **investigating enery efficiency level of mimo startegies in context of wirelesss sensor networks**
International Journal of Economic Perspectives, 11(1), 140-153
Retrieved from: https://ijeponline.org/index.php/journal/article

INVESTIGATING ENERY EFFICIENCY LEVEL OF MIMO STARTEGIES IN CONTEXT OF WIRELESSS SENSOR NETWORKS

Shitiz Upreti Research Scholar
Branch: Electronics& Communication
Department: School of Engineering & Technology
Maharishi University of Information & Technology
(MUIT), Lucknow (U.P)

Dr. Mahaveer Singh Naruka (Professor)
Department: School of Engineering & Technology
Maharishi University of lnformation& Technology (MUIT), Lucknow (U.P)

ABSTRACT

Because of the large number of sensors and strict power restrictions, wireless sensor networks differ from other types of wireless networks. To increase channel capacity and connection dependability, MIMO, a proven technology, has been included into current wireless broadband standards (multiple input, multiple output). New technologies are required to meet the growing demand for wireless data transfer. For both theory and execution, large MIMO antenna arrays constitute a paradigm change, since tens or hundreds of antennas allow for huge increases in throughput and energy efficiency over single antenna systems. In this study, we will look at MIMO, WSN, and associated protocols in an effort to minimise power consumption and boost energy efficiency. As a result, the cooperative V-MIMO system's efficiency and throughput are scrutinised.

Keywords: Virtual, Wireless, Energy, Network, Sensor, Protocols.

I. INTRODUCTION

“Wireless sensor networks (WSNs) are receiving a lot of interest from researchers because they may be used in a variety of disciplines, including habitat monitoring, object tracking, military systems, industrial automation, and home automation[1]. In most cases, the batteries that power sensor nodes have a limited lifetime and cannot be recharged. In wireless sensor networks, the issue of energy is still a major hurdle to broad implementation. In WSNs, there are a variety of ways to preserve energy,such as reducing transmit power, condensing data for transmission, or a combination of the two methods. A single-input–single-output (SISO) system would need more transmit power to achieve the same bit-error-rate and throughput performance requirements when employing MIMO to create diversity in a wireless network.[2]A wireless sensor node, on the other hand, is unable to accommodate a large number of antennas because of its size, cost, or hardware constraints. Using scattered antennas on a set of surrounding nodes, a cooperative MIMO technique is recommended in WSNs to boost energy efficiency by reducing transmit power through transmit power

[1] I. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, “A survey on sensor networks,” IEEE Comm. Mag., vol. 40, no. 8, pp. 102-114, Aug. 2002

[2] A. Paulraj, R. Nabar, and D. Gore, Introduction to Space-Time Wireless Communications, Cambridge, U.K.: Cambridge Univ. Press, 2003

***Corresponding author**: Shitiz Upreti*
Submitted: 26Oct 2017, Revised: 09 Nov2017, Accepted: 25 Dec 2017

reduction. In a cluster, sensor nodes work together to reduce energy consumption in so-called long-haul communication. According to studies, cooperative MIMO systems use less energy than non-cooperative or SISO systems while transmitting and receiving data simultaneously. In terms of energy efficiency, cooperative MIMO systems beat SISO systems, even after taking into account the additional training overhead necessary in MIMO systems and the varying channel propagation conditions. The total energy consumption of the model proposed in may be further reduced by balancing power distribution between intra-cluster (local) and inter-cluster (long-haul) transmissions[3]."

Long-haul transmission may conserve energy by using the data aggregation strategy to reduce the amount of data sent. Other applications such as environmental monitoring might benefit from spatially connected data from sensors in the surrounding area.Data aggregation has long been seen as a necessary technique for integrating such data in order to eliminate duplication and reduce the number of transfers, resulting in lower energy usage[4]. "Some researches have been published that integrate data aggregation with other energy-saving approaches in WSNs, such as cluster-based routing, channel assignment, and power scheduling protocols."

II. CONCEPT OF WIRELESS SENSOR NETWORKS (WSN)

An organisation is made up of a few pieces separated by short or substantial distances and spread out over a small or large area. Interconnected elements will be able to communicate with one another. The correspondence section consumes the majority of the organization's energy. As a result, remarkable correspondence frameworks at the real layer were being planned at the time. Previously, bent pair wires were the most common method of connecting the parts for communication. Then, instead of bent pairs, coaxial connections were used for recurrence to exceedingly high recurrence. Around the 1950s, with the advancement and improvement of technology, coaxial connections were replaced by waveguides for greater recurrence microwave correspondence. Furthermore, advancements in the correspondence field have resulted in the expansion of distant innovation to associate substances[5]. Wireless Sensor Networks are an organisation that consists of various sensor hubs connected to end-clients and linked via remote correspondence innovation through the channels (WSN)[6].

Several times, the wireless sensor network may be required to operate on performance and bandwidth-limited wireless communications media. These radio frequencies' microwave, infrared, and optical spectrums are used by RF-based wireless communications networks. The huge sensing network can absorb more electricity, and hence more energy. A network that uses less electricity to accomplish more data transitions is referred to as an energy-efficient WSN. Because a vast sensor network with low-powered batteries has already been installed, energy economy is a critical aspect for constructing the WSN. On the other hand, data transmission speed should be increased as needed; as a result, energy efficiency in soil monitoring must be increased for WSN.

---

[3] Z. Zhou, S. Zhou, S. Cui, and J. Cui, "Energy-Efficient cooperative Communication in a clustered wireless sensor network," IEEE Trans. Veh. Techno., vol. 57, no. 6, pp. 3618-3628, Nov. 2008.

[4] L. Krishnamachari, D. Estrin, and S. Wicker, "The impact of data aggregation in wireless sensor networks," in Proc. 22nd Int. Conf. on Distributed Computing Systems Workshops, Jul. 2002, pp. 575 - 578.

[5] Y. Gai, L. Zhang, and X. Shan, "Energy efficiency of cooperative MIMO with data aggregation in wireless sensor networks," in Proc. IEEE Wireless Communications and Networking Conf., Mar. 2007, pp. 792-797.

[6] Yanbing Zhang and Huaiyu Dai. Energy-efficiency and transmission strategy selection in cooperative wireless sensor networks. Journal of Communications and networks, 9(4), December 2007.

Corresponding author: **Shitiz Upreti**
Submitted: 26Oct 2017, Revised: 09 Nov2017, Accepted: 25 Dec 2017

How to Cite:
Shitiz Upreti and Dr. Mahaveer Singh Naruka (Dec 2017) **investigating enery efficiency level of mimo startegies in context of wirelesss sensor networks**
International Journal of Economic Perspectives, 11(1), 140-153
Retrieved from: https://ijeponline.org/index.php/journal/article

For long-distance data transport, "wireless" means without using any wires or other forms of electrical conductivity. With wireless communication, data may be sent wirelessly from one device to another. Since wireless networking technology enables people to communicate even if they are miles apart, it has become an essential element of many communication equipment. Wireless communication uses a broad variety of hardware devices, including cordless phones, mobile phones, GPS systems, and ZigBee technologies. A WSN is a collection of sensor nodes that can gather and transmit data wirelessly. They can detect and communicate with a central gateway various parameters. It is possible to connect WSN sensors and hardware processing boards using various communication techniques.

The following are some of the advantages of using WSN:

There are several reasons why WSN is widely used in applications such as ad hoc networks, health care, and soil monitoring. The following are some of the key advantages:

1. There is no need for a pre-existing framework to set up a WSN Network.
2. WSN is best for regions that are difficult to reach, such as the sea or the mountains, rural country areas, and so on.
3. The WSN is scalable and adaptable, which means that additional WSN nodes or routers may be added to the network as needed.
4. Automation improves productivity and connectedness.
5. The use of a wireless network eliminates the requirement for a large number of physical connections or cables.
6. Using WSN in agriculture makes it smarter by increasing productivity while lowering costs.

There is clearly a disadvantage in that WSN relies on battery power, limiting its lifespan. Networks aren't very safe. However, this is a benefit in terms of soil application. Their transmission speed is slow. Due to the employment of numerous electrical gadgets for acquisition and transmission, installing the WSN is even more expensive. As a result, these constraints are driving the development of an energy-efficient WSN network. It must be designed at the lowest possible cost and with the least amount of electricity.

WSN Protocol Classification

With better routing algorithms, the WSN's energy efficiency may be increased. That can route data according to the demands of the WSN network and systems[7]. This section looks at some of the most widely used energy-efficient WSN routing techniques. For WSN clustering-based protocols, the protocols discussed here are the “Power-Efficient GAthering for Sensor Information Systems” (PEGASIS), “Low-Energy Adaptive ClusteringHierarchy” (LEACH), and Deterministic Energy Efficient (DEC)[8]. Many of the current routing protocols use network clustering.

---

[7]“https://www.elprocus.com/introduction-to-wireless-sensor-networks-types-ndapplications/ Wireless Sensor Networks and their Applications.”

[8]Li, L., & Li, D. ―An energy-balanced routing protocol for a wireless sensor network‖, Journal of Sensors, Volume- 2017, Article ID 8505616, pp.1-12, 2017.

Corresponding author: ***Shitiz Upreti***
Submitted: 26Oct 2017, Revised: 09 Nov2017, Accepted: 25 Dec 2017

How to Cite:
Shitiz Upreti and Dr. Mahaveer Singh Naruka (Dec 2017) **investigating enery efficiency level of mimo startegies in context of wirelesss sensor networks**
International Journal of Economic Perspectives, 11(1), 140-153
Retrieved from: https://ijeponline.org/index.php/journal/article

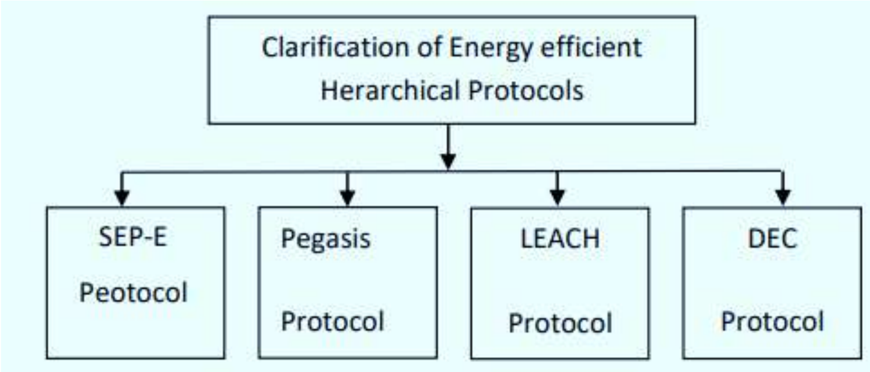

Figure 1 Classification of The WSN Routing Protocols

Figure 1 depicts a high-level overview of "energy-efficient clustering-based wireless routing" methods. All of the other protocols have been deemed superior than the basic LEACH procedure.

III. MIMO APPROACH

Assuming Mt neighbouring nodes have data to communicate, the MIMO-based WSN architecture is predicated on this assumption. "Using Alamouti diversity codes, each node broadcasts its data to the other nodes at discrete time intervals[9]. An Alamouti MIMO system makes use of the I "th node to send the transmission sequence to the I "th antenna across great distances."

Data is encoded and sent to the Mr -1 nodes (including the destination node) on the receiver side, which then decodes it into r n bits before sending it to the destination node[10].

With the potential to boost wireless channel capacity and connection reliability, "multi-input multiple-output" (MIMO) systems have lately attracted attention.Spatial multiplexing and diversity are discussed in this section as are MIMO systems. Massive MIMO systems are also shown to be an extension of the MIMO principle.

"***Benefits of MIMO Systems"***

For example, MIMO systems boost performance because of array gains, diversity gains, and space multiplexing gains. Consider aNt-transmit and Nr-receive system, known as Nt*Nr MIMO. In the following, each of these advantages is briefly discussed.

[9] G. J. Foschini and M. J. Gans (1998), ''On Limits of Wireless Communication in a Fading Environment when Using Multiple Antennas,'' Wireless Personal Communications, Vol. 6, No. 3, pp. 311-335

[10] S. Cui, A. Goldsmith and A. Bahai (2004), Energy-efficiency of MIMO and Cooperative MIMO Techniques in Sensor Networks , IEEE Journal on Selected Areas in Communications, Vol. 22, No. 6, pp. 1089-1098, Aug

Corresponding author: ***Shitiz Upreti***
Submitted: 26Oct 2017, Revised: 09 Nov2017, Accepted: 25 Dec 2017

How to Cite:
Shitiz Upreti and Dr. Mahaveer Singh Naruka (Dec 2017) **investigating enery efficiency level of mimo startegies in context of wirelesss sensor networks**
International Journal of Economic Perspectives, 11(1), 140-153
Retrieved from: https://ijeponline.org/index.php/journal/article

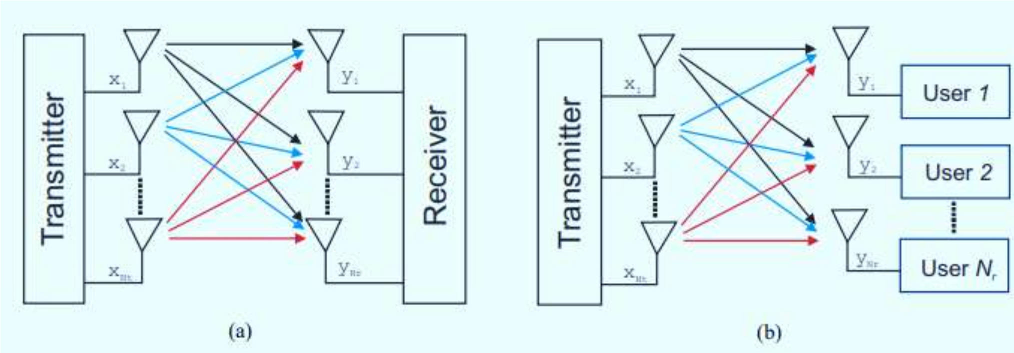

Figure 2: "Schematic representation of a (a) point-to-point and (b) multi-user MIMO wireless system, with aNt-antenna transmitter and Nr-antenna receiver or Nr single-antenna users, respectively."

Array Gain

As a result of wireless signals being coherently mixed at a receiver, array gain refers to an improvement in receive SNR[11]. Both transmit and receive antenna arrays must have channel information in order to establish coherence, and the number of transmit and receives is a factor in determining how many antennas are needed to achieve coherence. Enhances wireless network coverage by enhancing the system's ability to withstand interference[12].

Gain in diversity

In a wireless system, the intensity of the signal received varies at random (or fades). Multiple (ideally independent) copies of the signal are sent to the receiver in order to reduce fading in wireless networks[13]. There is a greater chance that at least one of the independent copies will not fade out, which improves reception quality and reliability. "It is possible to achieve spatial diversity on the order of Nt*Nr using a MIMO system that has Nt transmit and Nr receive antennas and Nt fading links."

"Gain in Spatial Multiplexing"

"MIMO systems provide a linear (in terms of the number of transmit-receive antenna pairs) or min(Nt, Nr) increase in capacity with no extra power or bandwidth[14]."Sending numerous separate data transmissions from each antenna results in a "spatial multiplexing boost." Certain conditions, such as high dispersion, allow the receiver to differentiate these streams of data. Space multiplexing may be performed utilising several detector designs, including maximum likelihood (ML), "zero-forcing" (ZF)," minimal mean-square error" (MMSE), and "successive interference cancellation" (SIC) detectors. MIMO channels often have a maximum number of data streams that can be accommodated, which is typically equal to max (Nt , Nr).

[11] A. J. Paulraj, D. A. Gore, R. U. Nabar, and H. Bolcskei, "An overview of MIMO communications - a key to gigabit wireless," Proceedings of the IEEE, vol. 92, pp. 198–218, Feb 2004.

[12] E. Biglieri, R. Calderbank, A. Constantinides, A. Goldsmith, A. Paulraj, and H. V. Poor, MIMO Wireless Communications. New York, NY, USA: Cambridge University Press, 2007.

[13] M. Gonzalez-Perez and J. Thompson, "Energy efficient inhomogeneous cellular networks," submitted to IEEE Transactions of Green Communications and Networking, December 2017

[14] E. Telatar, "Capacity of multi-antenna gaussian channels," Transactions on Emerging Telecommunications Technologies, vol. 10, no. 6, pp. 585–595, 1999.

***Corresponding author**: Shitiz Upreti*
Submitted: 26Oct 2017, Revised: 09 Nov2017, Accepted: 25 Dec 2017

How to Cite:
Shitiz Upreti and Dr. Mahaveer Singh Naruka (Dec 2017) **investigating enery efficiency level of mimo startegies in context of wirelesss sensor networks**
International Journal of Economic Perspectives, 11(1), 140-153
Retrieved from: https://ijeponline.org/index.php/journal/article

Fading MIMO Channel Capacity

MIMO systems may outperform standard "single-input single-output (SISO) systems"by merging techniques to diversity and spatial multiplexing together. This section discusses the benefits of MIMO technology in terms of system capacity.

ABOUT VIRTUAL MIMO

Sensors in a virtual MIMO network work together to communicate information. Long-distance transmissions may save a substantial amount of energy by using several sending and receiving devices, but circuitry power consumption climbs as the number of units increases[15]. As a result, measures for reducing energy use must take environmental factors into consideration. Because of the complexity of the circuitry and the difficulty in integrating numerous antennas, WSNs employ virtual MIMO techniques for "energy-efficient communication" in order to conserve energy and improve reliability.This study focuses on cooperative virtual MIMO, which uses shared data transmission and reception to enable energy-efficient communication.

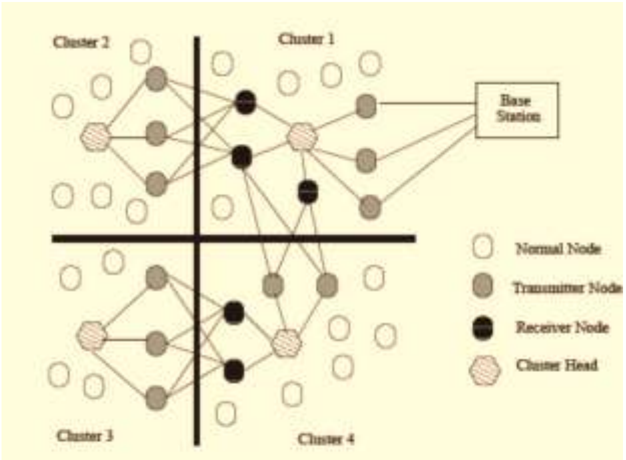

Figure 3: Virtual MIMO Network

Different numbers of nodes may be used to transmit and receive signals in the four clusters shown in Figure 3. Each node in Cluster 1 has direct access to the base station. Receiver nodes in Cluster 1 and Cluster 2 are connected by three nodes in Cluster 2.Cluster 2 communicates with cluster 1, then cluster 1 communicates with the base station, resulting in a multi-hop communication network topology. This is also the case with Cluster 4's two transmitter nodes, which link to Cluster 1's two receiver nodes. Clusters 2 and 4 broadcasters share the same receiving node in Cluster 1. There are several transmitters that might utilise the same receiver node. In order to access the cluster 3 base station, you may utilise either Cluster 2 or Cluster 4.However, Cluster 4 was selected for MIMO communication since it uses less energy than Cluster 2. Energy and current load needs are taken into account while selecting cluster heads (CHs)[16].

[15] Y. Yuan, Z. He and M. Chen (2006), "Virtual MIMO-based Cross-layer Design for Wireless Sensor Networks", IEEE Transactions on Vehicular Technology, Vol. 55, pp. 856 864, May.

[16]Wenqing Chen, Yong Yuan, Changchun Xu, and KezhongLiuandZongkai Yang, Virtual Mimo Protocol Based on Clustering for Wireless Sensor Network. Computers and Communications, 2005, ISCC 2005, Proceedings, 10th IEEE Symposium, 2005b

Corresponding author: ***Shitiz Upreti***
Submitted: 26Oct 2017, Revised: 09 Nov2017, Accepted: 25 Dec 2017

How to Cite:
Shitiz Upreti and Dr. Mahaveer Singh Naruka (Dec 2017) **investigating enery efficiency level of mimo startegies in context of wirelesss sensor networks**
International Journal of Economic Perspectives, 11(1), 140-153
Retrieved from: https://ijeponline.org/index.php/journal/article

IV. ENERGY EFFICIENCY OF VIRTUAL MIMO

Because of its energy efficiency in wide field networks, virtual MIMO has lately piqued the attention of many researchers and practitioners. Virtual MIMO networks are made up of many sensors that work together to transmit and receive data[17]. As the number of transmitters and receivers increases, so does the circuitry's power consumption, making long-range communications less efficient. As a result, environmental considerations must be included into energy efficiency measures. It is possible to decrease the complexity of the circuitry and the difficulties of integrating different antennas in WSNs by using virtual MIMO principles, which are energy efficient and more reliable.

A wide variety of protocols and methodologies have been proposed for WSN energy efficiency.In this work, we'll look at how LEACH[18] incorporates “cooperative virtual MIMO” to “enable energy-efficient communication” by “sharing information transmission and reception.”Long-distance communication may be made more reliable by using many senders and receivers, a method known as "virtual MIMO." Topology of the network and data link layers affects virtual MIMO in WSNs. There are several ways to build virtual antenna arrays in WSNs.

The physical layer is in charge of establishing cooperative transmission and virtual antenna arrays, but it is also in charge of implementing on this subject. In a cognitive network design, the operational settings of network components may be changed to meet the needs of the environment. Cluster-based virtual MIMO is integrated in the LEACH cognitive model in order to adjust operational parameters (constellation size) to reach the best design.

“For wireless cellular and broadband access systems, MIMO's enormous theoretical capacity of multi-path fading channels has made it extensively used. Whether this strategy can be used to conserve energy in WSN will be an intriguing test. By taking into account the power used by both the circuitry and the transmission, the author devised a technique for estimating the energy efficiency of MIMO and cooperative MIMO systems. Virtual MIMO is more energy efficient than multiple input multiple output when transmission distance reaches a particular threshold (MIMO).”

Because of the physical size and power constraints of sensor nodes, it is not practical to implement MIMO in a single node. On the other hand, cooperative sensor nodes might use the virtual MIMO technique in sensor networks. STBC virtual MIMO, for example, incorporates the training overhead necessary for MIMO transmissions into its design. Another idea is to use multi-hop MIMO transmission to lower the amount of energy needed to communicate across clusters of nodes. However, the sink is situated close to or inside the sensor area in this configuration. Because long-distance transmission energy consumption outweighs the energy expenditure, multi-hop MIMO transmission is unneeded in circumstances when the sink is far from the sensor region[19].

---

[17]“SajidHussain Â· AnwarulAzim Â· Jong Hyuk Park Energy Efficient Virtual MIMOCommunication for Wireless Sensor Networks Oct 1, 2009 Academic edition. Telecommunication Systems. October 2009, Volume 42,”

[18]“JieDing,Danpu Liu, Xin Wang, Huari Wu An Energy- Efficient Virtual MIMO Transmission Scheme for Cluster- based Wireless Sensor Networks by J Ding Jan 11,2010”

[19]S. K. Jayaweera, Virtual MIMO-based Cooperative Communication for Energy-constrained Wireless Sensor Networks, IEEE Trans. On Wireless Communications, vol. 5, pp. 984989, May 2006

Corresponding author: ***Shitiz Upreti***
Submitted: 26Oct 2017, Revised: 09 Nov2017, Accepted: 25 Dec 2017

How to Cite:
Shitiz Upreti and Dr. Mahaveer Singh Naruka (Dec 2017) **investigating enery efficiency level of mimo startegies in context of wirelesss sensor networks**
International Journal of Economic Perspectives, 11(1), 140-153
Retrieved from: https://ijeponline.org/index.php/journal/article

V. "ENERGY EFFICIENCY OF MIMO TRANSMISSION STRATEGIES IN WIRELESS SENSOR NETWORKS"

With extensive sensor deployment and strict power constraints, wireless sensor networks differ from traditional wireless networks[20]. In hostile communication situations, close-knit sensor groups must cooperate to realise the full potential of wireless sensor networks."By enabling sensor nodes to communicate cooperatively in MIMO systems, recent advances in wireless MIMO communications may enhance system throughput or, equivalently, decrease energy consumption for the same throughput and bit error rate(BER) objective. This is critical for sensors."

Most sensor nodes only have one antenna because of their small size and low power consumption. Using non-linear arrays of sensors for communication purposes, researchers have lately developed a novel approach to sensor networks that makes it possible to apply advanced spacetime coding and processing methods. When assessing the energy efficiency of MIMO transmission systems in sensor networks, it is necessary to take into account both the circuit energy consumption and the cooperation penalty. Because cooperative MIMO systems are used in short-range applications like sensor networks, the power consumption of the circuit increases linearly with the increase in the number of cooperative nodes. Cooperative nodes must interact with each other for MIMO transmissions since the virtual antenna array's components are not connected. Cooperative 22 MIMO is more energy efficient than a typical single-input single-output (SISO) algorithm when the transmission distance surpasses a certain threshold, according to a recent study.[21]. In our study, we make the following assumptions. Antenna arrays, complex CPUs, and transceivers all go into making powerful mobile agents (MA) on the receiving end. So although sophisticated detection methods may be employed safely, their energy consumption can be eliminated from all sensor network's budget, enabling us to focus on energy analysis at the cooperative transmission end."Second, in addition to STBC methods[22], spatial multiplexing (SM, also known as BLAST)[23]is examined in depth, both for wideband asymptotes and for more realistic systems."After that, the SM approaches are tested in real-world systems with both optimal and suboptimal detections, together with fixed and adaptive signalling. Analytical information is supplied as soon as it's accessible.

<u>Energy Efficient Massive MIMO Wireless Networks</u>

"In Energy Efficient Massive MIMO Wireless Networks, the energy efficiency and throughput of a V-MIMO system using a large transmit antenna array and DF cooperation among the user terminals are examined. These are the chapter's most important contributions: the influence on system performance of imperfect CSI is analysed, and a power allocation mechanism to decrease power consumption is implemented when available resource blocks are restricted. Simulated findings show that the highest throughput may be attained when

[20] I. F. Akyildiz et al., "A survey on sensor networks", IEEE Communications Magazine, vol. 40, no. 8, pp.102 - 114, Aug. 2002

[21] S. Cui, A. J. Goldsmith and A. Bahai, "Energy-efficiency of MIMO and cooperative MIMO in sensor networks," IEEE J. Select. Areas Commun., vol. 22, no. 6, pp. 1089-1098, Aug. 2004.

[22] V. Tarokh, H. Jafarkhhani and A. R. Calderbank, "Space-time block codes from orthogonal designs," IEEE Trans. Inform. Theory, vol. 45, no. 5, pp. 1456 -1467, July 1999.

[23] G. J. Foschini, "Layered space-time architecture for wireless communication in a fading environment when using multi-element antennas," Bell Labs Tech. J., vol. 2, no. 2, pp. 41-59, 1996.

***Corresponding author**: Shitiz Upreti*
Submitted: 26Oct 2017, Revised: 09 Nov2017, Accepted: 25 Dec 2017

resource blocks are not restricted[24]. However, cooperative methods may be employed to meet data rate requirements in the actual world when a large number of users share frequency resources. This wireless cooperation between users is more energy efficient than using a high modulation order transfer in the case of low resource block utilisation. It has also been shown that the more transmit antennas there are, the less impact CSI errors have on system performance."

Model for Energy Efficiency

This section's purpose is to figure out how much power the virtual MU-MIMO system will need in total. For both downlink and cooperative connections, the total power used by the BS, destination, and relay nodes, plus a specified constant to allow for load-independent power consumption, is computed[25].

Model of Power Consumption

Virtual MU-power MIMO's consumption is calculated by evaluating the three primary components of the network from a power modelling perspective: For example, (a) the multi-antenna BS, and (b) relay collaboration.

"For each base station in the network, the power consumption model should take into consideration the PA, analogue front end, digital baseband, control and network backhaul, and power systems[26]. Models in [7, 55, 129] are used to simulate the power consumption at the base station (BS) of a hypothetical MU-MIMO system."

$$P_{\mathrm{BS}} = \frac{1}{\delta}P + N_t P_{\mathrm{ct}} + m_s^b N_r P_{\mathrm{cod}} + P_{\mathrm{lo}}$$

Because sk is part of an M-QAM constellation, the bit rate per data symbol is given by mb s = log2 (M). Circuit components (such as converters and mixers) need a certain amount of power (Pct), which is directly proportional to the number of transistors (Nt). Number of user terminals and modulation effectiveness both affect Pcod, also known as power coding. Local oscillator power (Plo) is a different matter entirely.

"One-shot connections between the receiver cluster, which includes the destination and relay nodes, are regarded to be near together. It is necessary for each relay to decode, encode, and re-transmit the signal to the destination node. Therefore, the power consumption on the receiver side must take into account the UEs' circuit power consumption, signal processing power consumption, and the transmit power required for wireless cooperation. Using this formula, you may figure out how much power the receiver is using:"

$$P_{\mathrm{UE}} = N_r P_{\mathrm{cr}} + N_c N_d P_r + m_s^b N_r N_d P_{\mathrm{cod}} + m_s^b (N_r + N_c N_d) P_{\mathrm{dec}}$$

[24] S. Cui, A. J. Goldsmith, and A. Bahai, "Energyefficiency of MIMO and cooperative MIMO techniques in sensor networks," IEEE Journal on Selected Areas in Communications, vol. 22, no. 6, pp. 1089–1098, 2004.

[25] Yong Yuan and Zhihai He. Virtual MIMO-based crosslayer design for wireless sensor networks. Vehicular Technology, IEEE Transaction, 55(3), May 2006a.

[26] B. Debaillie, C. Desset, and F. Louagie, "A flexible and future-proof power model for cellular base stations," in 2015 IEEE 81st Vehicular Technology Conference (VTC Spring), pp. 1–7, May 2015.

Corresponding author: *Shitiz Upreti*
Submitted: 26Oct 2017, Revised: 09 Nov2017, Accepted: 25 Dec 2017

How to Cite:
Shitiz Upreti and Dr. Mahaveer Singh Naruka (Dec 2017) **investigating enery efficiency level of mimo startegies in context of wirelesss sensor networks**
International Journal of Economic Perspectives, 11(1), 140-153
Retrieved from: https://ijeponline.org/index.php/journal/article

Each UE consumes Pcr of circuit power, whereas each relay transmits Pr. Based on this assumption, the power distribution ratio between the relay and the transmitter is defined as = Pr/P. P helps the relay decide on its own transmit power because of this information. Prior to retransmission, Pdec and Pcod determine how much power is required for decoding and recoding, respectively."A constant number Po is also considered[27], fixed power usage for backhaul infrastructure, control signals, and site cooling is taken into consideration.To conclude, the following is a summary of the power usage of the cooperative system:"

Pcons = PBS + PUE + Po.

Energy Efficiency Analysis

First and foremost, the BS is believed to only serve a limited number of UEs. BSs are therefore allowed to use several resource blocks per destination node in order to reach their desired rate of transmissions. With an unlimited amount of resource blocks, Nrb carriers may support the kth UE, since each resource block has just one time and frequency slot available to them. The amount of resource blocks allocated to each user terminal may restrict the number of strategies that may be used to fulfil the user's requirement for data rate in a realistic situation. Creating a collaborative wireless system where the number of relays servicing each destination node boosts throughput is possible. The modulation order of each beam may, however, be increased. Precoding makes it possible for a large number of UEs to share the same time-frequency resources in these different contexts.

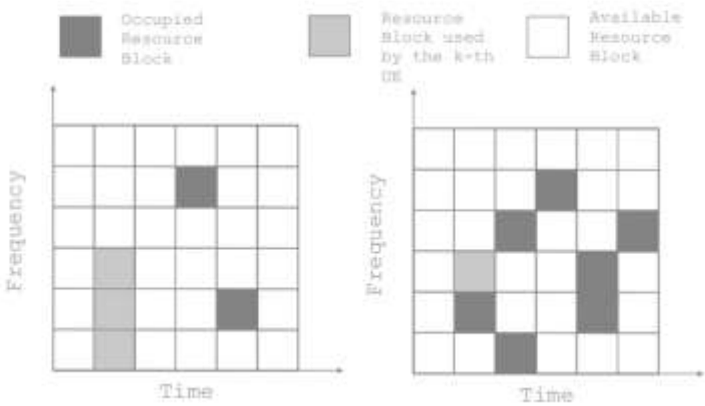

Figure 4: "The network under low traffic load (left) and high traffic load (right) is depicted graphically. The black, grey, and white boxes represent the time-frequency resource blocks that are occupied, those that are utilised by the planned k-th user, and those that are available for transmission, respectively."

Figure 5 depicts a visual depiction of two different network traffic load scenarios. Because the network on the left is under minimal traffic strain, the k-th user's resource blocks are not limited. Due to an increase in network traffic, the BS must now either choose other time-resource blocks for transmission or increase the modulation order per beam in order to keep up with demand.

[27] E. Bjrnson, L. Sanguinetti, J. Hoydis, and M. Debbah, "Optimal design of energyefficient multi-user MIMO systems: Is massive MIMO the answer?," IEEE Transactions on Wireless Communications, vol. 14, pp. 3059–3075, June 2015.

Corresponding author: Shitiz Upreti
Submitted: 26Oct 2017, Revised: 09 Nov2017, Accepted: 25 Dec 2017

How to Cite:
Shitiz Upreti and Dr. Mahaveer Singh Naruka (Dec 2017) **investigating enery efficiency level of mimo startegies in context of wirelesss sensor networks**
International Journal of Economic Perspectives, 11(1), 140-153
Retrieved from: https://ijeponline.org/index.php/journal/article

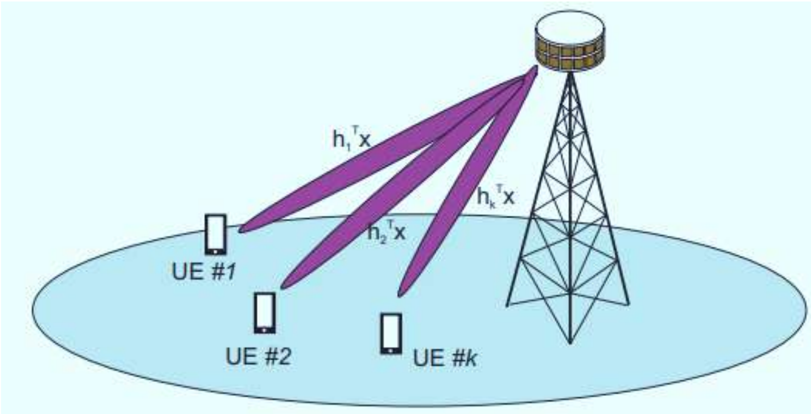

Figure 5: "Base station simultaneously transmitting to multiple single-antenna users"

According to the block error rate (BLER), a system's throughput may be measured by the number of successfully received bits.[28]. It is possible to express the number of unintentionally received bits at the k-th destination node as follows:

$$T_k = m_s^b[(1 - \mathbb{P}_{e,d}) + N_c(1 - \mathbb{P}_{e,r})]$$

"The block error probability at the destination and relay nodes, respectively, is Pe,d and Pe,r. With Nd ≥ 1 destination nodes, $\sum_{k=1}^{N_d} T_k$Tk gives the packet throughput per channel used, which is measured in bits/s[29]. If the system is allowed to use more than one resource block and the transmit power per resource block is P/Nrb, the effective packet throughput for the virtual MU-MIMO[30] using the N_{rb} available resource blocks is"

$$E_T = N_{rb} \sum_{k=1}^{N_d} T_k$$

"Finally, the average energy efficiency can be defined as"

$$EE = \frac{E_T}{P_{\text{cons}}} \qquad \text{[bits/J]}$$

I. CONCLUSION

Many well-known MIMO transmission algorithms are examined for their energy efficiency in a hierarchical wireless sensor network. Virtual MU-MIMO systems employ multiple

[28] G. Miao, "Energy-efficient uplink multi-user MIMO," IEEE Transactions on Wireless Communications, vol. 12, pp. 2302–2313, May 2013.

[29] Y. Yao, X. Cai, and G. B. Giannakis, "On energy efficiency and optimum resource allocation of relay transmissions in the low-power regime," IEEE Transactions on Wireless Communications, vol. 4, pp. 2917–2927, Nov 2005.

[30] H. Q. Ngo, E. G. Larsson, and T. L. Marzetta, "Massive MU-MIMO downlink TDD systems with linear precoding and downlink pilots," in 2013 51st Annual Allerton Conference on Communication, Control, and Computing (Allerton), pp. 293–298, Oct 2013.

***Corresponding author**: Shitiz Upreti*
Submitted: 26Oct 2017, Revised: 09 Nov2017, Accepted: 25 Dec 2017

antennas to broadcast data and work together with single antenna receivers that are near to one other. Wireless networks may benefit from large multi-antenna systems, but at the cost of greater circuit power consumption due to the numerous radio frequency chains used, their spectral efficiency suffers. Energy efficiency and effective throughput were explored in this chapter. In order to provide a common framework, one model of power consumption was established to take into account not only the transmit and circuit power needed at the transmitter, but also the overhead power consumption imposed by wireless collaboration. Channel state information was used to assess both the cooperative's throughput and energy efficiency.

REFERENCES: -

[1] J. Paulraj, D. A. Gore, R. U. Nabar, and H. Bolcskei, "An overview of MIMO communications - a key to gigabit wireless," Proceedings of the IEEE, vol. 92, pp. 198–218, Feb 2004.

[2] Paulraj, R. Nabar, and D. Gore, Introduction to Space-Time Wireless Communications, Cambridge, U.K.: Cambridge Univ. Press, 2003

[3] Debaillie, C. Desset, and F. Louagie, "A flexible and future-proof power model for cellular base stations," in 2015 IEEE 81st Vehicular Technology Conference (VTC Spring), pp. 1–7, May 2015.

[4] Ha, K. Lee, and J. Kang, "Energy efficiency analysis with circuit power consumption in massive MIMO systems," in 2013 IEEE 24th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC), pp. 938–942, Sept 2013.

[5] Biglieri, R. Calderbank, A. Constantinides, A. Goldsmith, A. Paulraj, and H. V. Poor, MIMO Wireless Communications. New York, NY, USA: Cambridge University Press, 2007.

[6] Bjrnson, L. Sanguinetti, J. Hoydis, and M. Debbah, "Optimal design of energyefficient multi-user MIMO systems: Is massive MIMO the answer?," IEEE Transactions on Wireless Communications, vol. 14, pp. 3059–3075, June 2015.

[7] Telatar, "Capacity of multi-antenna gaussian channels," Transactions on Emerging Telecommunications Technologies, vol. 10, no. 6, pp. 585–595, 1999.

[8] J. Foschini and M. J. Gans (1998), "On Limits of Wireless Communication in a Fading Environment when Using Multiple Antennas," Wireless Personal Communications, Vol. 6, No. 3, pp. 311-335

[9] J. Foschini, "Layered space-time architecture for wireless communication in a fading environment when using multi-element antennas," Bell Labs Tech. J., vol. 2, no. 2, pp. 41-59, 1996.

[10] G. Miao, "Energy-efficient uplink multi-user MIMO," IEEE Transactions on Wireless Communications, vol. 12, pp. 2302–2313, May 2013.

***Corresponding author**: Shitiz Upreti*
Submitted: 26Oct 2017, Revised: 09 Nov2017, Accepted: 25 Dec 2017

[11] Q. Ngo, E. G. Larsson, and T. L. Marzetta, "Massive MU-MIMO downlink TDD systems with linear precoding and downlink pilots," in 2013 51st Annual Allerton Conference on Communication, Control, and Computing (Allerton), pp. 293–298, Oct 2013.

[12] https://www.elprocus.com/introduction-to-wireless-sensor-networks-types-ndapplications/ Wireless Sensor Networks and their Applications.

[13] Hussain, S., Azim, A., & Park, J.H. (2009). Energy efficient virtual MIMO communication for wireless sensor networks. *Telecommunication Systems, 42*, 139-149.

[14] Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "A survey on sensor networks," IEEE Comm. Mag., vol. 40, no. 8, pp. 102-114, Aug. 2002

[15] F. Akyildiz et al., "A survey on sensor networks", IEEE Communications Magazine, vol. 40, no. 8, pp.102 -114, Aug. 2002

[16] Jiang, Virtual-MIMO Systems with Compress-and-Forward Cooperation. PhD thesis, The University of Edinburgh, 2011.

[17] JieDing,Danpu Liu, Xin Wang, Huari Wu An Energy- Efficient Virtual MIMO Transmission Scheme for Cluster- based Wireless Sensor Networks by J Ding Jan 11,2010

[18] Krishnamachari, D. Estrin, and S. Wicker, "The impact of data aggregation in wireless sensor networks," in Proc. 22nd Int. Conf. on Distributed Computing Systems Workshops, Jul. 2002, pp. 575 - 578.

[19] Li, L., & Li, D. ―An energy-balanced routing protocol for a wireless sensor network‖, Journal of Sensors, Volume- 2017, Article ID 8505616, pp.1-12, 2017.

[20] Gonzalez-Perez and J. Thompson, "Energy efficient inhomogeneous cellular networks," submitted to IEEE Transactions of Green Communications and Networking, December 2017

[21] S. Cui, A. Goldsmith and A. Bahai (2004), Energy-efficiency of MIMO and Cooperative MIMO Techniques in Sensor Networks , IEEE Journal on Selected Areas in Communications, Vol. 22, No. 6, pp. 1089-1098, Aug

[22] S. Cui, A. J. Goldsmith and A. Bahai, "Energy-efficiency of MIMO and cooperative MIMO in sensor networks," IEEE J. Select. Areas Commun., vol. 22, no. 6, pp. 1089-1098, Aug. 2004.

[23] S. Cui, A. J. Goldsmith, and A. Bahai, "Energyefficiency of MIMO and cooperative MIMO techniques in sensor networks," IEEE Journal on Selected Areas in Communications, vol. 22, no. 6, pp. 1089–1098, 2004.

***Corresponding author**: Shitiz Upreti*
Submitted: 26Oct 2017, Revised: 09 Nov2017, Accepted: 25 Dec 2017

How to Cite:
Shitiz Upreti and Dr. Mahaveer Singh Naruka (Dec 2017) **investigating enery efficiency level of mimo startegies in context of wirelesss sensor networks**
International Journal of Economic Perspectives, 11(1), 140-153
Retrieved from: https://ijeponline.org/index.php/journal/article
[24] S. K. Jayaweera, Virtual MIMO-based Cooperative Communication for Energy-constrained Wireless Sensor Networks, IEEE Trans. On Wireless Communications, vol. 5, pp. 984989, May 2006

[25] SajidHussain Â· AnwarulAzim Â· Jong Hyuk Park Energy Efficient Virtual MIMOCommunication for Wireless Sensor Networks Oct 1, 2009 Academic edition. Telecommunication Systems. October 2009, Volume 42,

[26] V. Tarokh, H. Jafarkhhani and A. R. Calderbank, "Space-time block codes from orthogonal designs," IEEE Trans. Inform. Theory, vol. 45, no. 5, pp. 1456 -1467, July 1999.

[27] Wenqing Chen, Yong Yuan, Changchun Xu, and KezhongLiuandZongkai Yang, Virtual Mimo Protocol Based on Clustering for Wireless Sensor Network. Computers and Communications, 2005, ISCC 2005, Proceedings, 10th IEEE Symposium, 2005b

[28] Y. Gai, L. Zhang, and X. Shan, "Energy efficiency of cooperative MIMO with data aggregation in wireless sensor networks," in Proc. IEEE Wireless Communications and Networking Conf., Mar. 2007, pp. 792-797.

[29] Y. Yao, X. Cai, and G. B. Giannakis, "On energy efficiency and optimum resource allocation of relay transmissions in the low-power regime," IEEE Transactions on Wireless Communications, vol. 4, pp. 2917–2927, Nov 2005.

[30] Y. Yuan, Z. He and M. Chen (2006), "Virtual MIMO-based Cross-layer Design for Wireless Sensor Networks", IEEE Transactions on Vehicular Technology, Vol. 55, pp. 856 864, May.

[31] Yanbing Zhang and Huaiyu Dai. Energy-efficiency and transmission strategy selection in cooperative wireless sensor networks. Journal of Communications and networks, 9(4), December 2007.

[32] Yong Yuan and Zhihai He. Virtual MIMO-based crosslayer design for wireless sensor networks. Vehicular Technology, IEEE Transaction, 55(3), May 2006a.

[33] Z. Zhou, S. Zhou, S. Cui, and J. Cui, "Energy-Efficient cooperative Communication in a clustered wireless sensor network," IEEE Trans. Veh. Techno., vol. 57, no. 6, pp. 3618-3628, Nov. 2008.

***Corresponding author**: Shitiz Upreti*
Submitted: 26Oct 2017, Revised: 09 Nov2017, Accepted: 25 Dec 2017