Journal of Advanced Research in Wireless, Mobile & Telecommunication
Volume 2, Issue 2 - 2019, Pg. No. 28-34
Peer Reviewed Journal

Article

Energy Efficient Communication Scheme in Wireless Sensor Network: A Comparative Review

Deepak Sopara[1], Shailaja Y. Kanawade[2], Vikas Soni[3]

[1,3]PG Scholar, Department of Electronics and Communication Engineering, Modi Institute of Technology, Naya GaonRawat bhata Road, Kota (Rajasthan), India.

[2]Associate Professor, Department of Electronics and Communication Engineering, Modi Institute of Technology, Kota-(Rajasthan), India.

[3]Professor Cum Principal, Modi Institute of Technology, Naya Gaon Rawatbhata Road, Kota-324 010 (Rajasthan), India.

I N F O

Corresponding Author:
Deepak Sopara, Department of Electronics and Communication Engineering, Modi Institute of Technology, NayaGaonRawatbhata Road, Kota (Rajasthan), India.
E-mail Id:
deepaksopara.giet12@gmail.com
How to cite this article:
Sopara D, Kanawade SY, Soni V. Energy Efficient Communication Scheme in Wireless Sensor Network: A Comparative Review. *J Adv Res Wire Mob Telecom* 2019; 2(2): 28-34.

Date of Submission: 2019-12-25
Date of Acceptance: 2020-02-02

A B S T R A C T

Wireless Sensor Networks (WSNs) are used in wide variety of applications. It consists of number of tiny sensor nodes which is operated on batteries. These battery operated nodes are deployed over a long period of time long to perform some specific task. Energy saving is major concern part of such applications. Reducing power consumption is one of the possible solution in WSN for longer lifetime. Communication is one of a major source of power drain in such networks. Hence many researchers all around the worldproposed energy efficient communication scheme to save energy at transmitter as well as at receiver.In this paper, a comparative review on such energy efficient communication schemesfor WSN.

Keywords: Energy Efficient Communication Scheme, Silent communication, Wireless Sensor Networks

Introduction

A Wireless Sensor Network (WSNs) typically consists of low power & low cost sensor devices which are deployed in areas which are difficult to access. In all such applications the sensor devices are battery powered and expected to operate over prolonged periods of time. Communication is one of a major source of power drain in such network; hence employment of energy efficient communication protocol with low hardware and software is important. In all such schemes, the underlying communication strategy of sending a string of binary bits is energy based transmission. In Energy based Transmissions (EbT) method transmission of every bit, 0 or 1, involves the expenditure of the same amount of energy. A various energy efficient techniques for WSNs are investigated. Most of them use the stream of x symbols to transmit through appropriate digital modulation scheme with remain silent during dominant symbol. In this silent period, the transmitter saves the significant amount of energy. But existing communication schemes not only utilize non- zero voltage levels for both 0 and 1 to distinguish between a silent and a busy channel but also keep both the transmitter and the receiver switched on for the entire duration of the transmission of a data frame. Communication strategies which require energy expenditure for transmitting both 0 and 1 bit values are known as energy based transmission (EbT) schemes.

This paperpresents a review of communication protocol which provides a highly energy efficient technique for data transmission.[19]

The paper is organized as follows: Section 1 gives the literature review related. Section2 presents performance analysis of different energy efficient communication schemeand section 3 presents conclusion while section 4 consist of references and Authors' Biography.

Literature Review

This section gives the brief introduction of different silent zero communication schemes for saving energy at the transmitter as well as at the receiver.

In this context, in 2005 Zhu and Sivakumar introduce a new communication strategy called Communication through Silence (CtS)[1] which involves the use of silent periods as opposed to energy based transmissions strategy that uses silent periods to convey information from the sender to the receiver. The conventional communication strategy Energy based Transmission (EbT) involves theuse of energy driven bit transmissions for sending information from a sender to a receiver. Generally, if the information to be sent by the sender at given instance spans k bits, the energy consumptions k□eb. If the start and stop signals can be sent with the same or lesser energy than eb, the total energy consumed is at most 2□eb, which is better by a factor of over 3 when compared to the EbT scheme. In CtS, instead of usinga signal pulse to represent each bit, the communication can beperformed by marking the start and the end of a period oftime to convey information. For example, in order to transmitvalue 97 between, a 7-bit string is usuallytransmitted using EbT and thus 7 units of energy is consumed.In contrast, in CtS, such information can be conveyed bysending a start mark and an end mark with an silent period of 97 time slots, resulting in 2 units of energy consumption intotal. CtS is innovative and can potentially result in significantenergy saving, but the biggest drawback of the CtS scheme is that the transmission time in CtS is exponential in the number of bits to be sent. Thusit introduces undesirably long delay and israther challenging in implementation. Some unsolved issues left by Cts are

- **Throughput** – CtS introduces long delay and thus affectsthe network throughput negatively. In particular, theloss in throughput is exponential to the gainin the energy.
- **Sender identity** – The inability of receivers'distinguishing the identities of message sender renders the through put enhancement, i.s. multiplexing and fast forwarding, impossible to implement.
- **Hidden terminals** – When two senders transmit to thesame receiver while they are not aware of each other,the transmissions collide at the receiver. This classic problem may compromise the transmission reliability considerably in CtS.[1]

Alternative to Cts in 2006 Chen et al., propose a new energy efficient communication scheme variable-base tacit communication (VarBaTaC) for sensor networks. VarBaTaC[2] generalizes both CtS and conventional binary coding based communications by using a variable coding base. For example, if a value 97 is to be transmitted and a base of 16 is chosen, it is first represented as (6, 1). The sender sends digit 6 and then digit 1 back to back using CtS for each digit. Compared to CtS, an extra pulse is inserted to separate these two digits. The delay introduced by CtS is thus controllable by the tuning the coding base and can be reduced significantly. (Compare the transmission time of 97 slots using CtS to that of 6+1 using VarbaTaC.) In essence, both CtS and conventional EbT communication schemes are special cases of VarBaTaC with bases infinity and 2.

Neither CtS [1] nor VarBaTaC [2] addresses theissue of determining the amount of energy saved for noisy channels.

In 2007 Sinha k., et al., propose a new energyefficient wireless communication technique using redundant radix representation In this redundant binary number (RBN) representation utilizing one of the signed – digit (SD) representation in which RBN has fixed radix 2 and a digit set { $\bar{1}$, 0, 1}, where $\bar{1}$ denotes -1. In RBNS, there can be more than one possible representation of a given number. An example of number 7 can be taken in to account which 7 can be represented as either 111 or 100$\bar{1}$ in RBNS. This property of RBNS reduces number of 1's in the string during transmitting the message. At the receiver side, the original binary message is received by reconverting the received message from RBNS to binary.[3]

Based on this transmission strategy a MAC protocol was designed bySinha k., et al. in 2008 that would support the communication of such RBN encoded data frames [4-6,9]. In 2009 a new energy efficient communication scheme Run-Zero-Encoding (RZE) was proposed for multihop wireless sensor networks.RZE communicationscheme utilizes the concepts of the RBNSiZeComm protocol. However, unlike RBNSiZeComm, RZE simultaneously saves energyat both the transmitter and receiver. Also, maintaining synchronization betweentransmitter and receiver is easier in RZE.[7,8]

Ternary with Silent Symbol (TSS) communication scheme is similar in concepts to the RBNSiZeComm protocol was proposed by Ghosh, et al., in 2008. Ternary with Silent Symbol (TSS) communication scheme which uses ternary encoding of datain which an efficient algorithm has been developed for conversion from binary to ternary and vice-versa with saving energy at both the transmitter and receiver.

Let a given binary message B be represented by an n-bit binary string bn−1bn−2 . . . b2b1b0. Let T be its equivalent m digit ternary representation given by equation (2)

T = tm−1tm−2 . . . t2t1t0. (2)

We assume that n is even, otherwise we pad the message with a 0 bit at the leftmost (msb) position. For conversion from binary to ternary, we successively scan every two bits of the binary message starting from its msb position and then convert the leftmost part of the binary message (starting from its msb to the currently scanned bit position) to its equivalentternary representation. To do this, we replace the currently scanned two bits (bit-pair) by either a single ternary digit (0, 1 or 2 depending on whether the binary bit-pair is 00, 01 or 10), or by two ternary digits (10)3 (if the binary bit-pair is 11), and then add it to four times the so far obtained ternary number T from all the previous bit positions (on the left of this bit-pair). Note that this addition will be in ternary number system, and the multiplying factor four is to adjust the weight of T with respect to the currently scanned bit-pair. Also, since this addition will be in ternary number system, the weight of four can be assigned to T by adding the two ternary numbers T0 and 0T. Thus, the equivalent ternary representation of the part of the binary message from its msb to the currently scanned bit-pair will then be obtained as T0⊕ 0T⊕ x, where ⊕ represents a ternary addition operator, and x is the ternary number equal to 0, 1, or 2 (when the scanned bit-pair is 00, 01 or 10, respectively), or equal to (10)3 (when the scanned bi-pair is 11).

TSS protocol generates energy savings simultaneously at the transmitter as well as at the receiverdue to shortening of the transmission duration.The average transmitter power of both the schemes is almost same.

In 2009 Sinha k. et al., carried out theperformance of RBNSiZe Comm using the non-coherent detection basedtransceiver implementation for the RBNSiZeComm protocol for communication over AWGN channels in the context of remote healthcare, multimedia streaming and agriculture wireless sensor networks.[8]

In 2010 Sinha k. et al., proposeda new energy-efficient communication scheme called CNS (Compression with Null Symbol) thatcombines the power of data compression and communication through silent symbol.CNS utilizes a radix 4 based encoding of binary data. The encoding process reduces the number of symbols to be communicated by a factor of 2, and hence the transmission duration.CNS generates savings at both the transmitter and receiver makes it particularly suitable for use in multi-hop wireless networks.Therefore, starting from the least significant bit (lsb) position of the binary data frame, every bit-pair (00, 01, 10 or 11) can be assumed to represent a CNS symbol. Henceforth, we shall refer to the four CNS symbols as A, B, C and N and the mapping of the bit pairs to the symbols as bit-pair to symbol mapping or BpS Mapping. The symbol N stands for Null to indicate communication through silent timeperiods or equivalently, null signal on the channel. As an example, for a particular scenario, the bit-pairs 00,01, 10 and 11may be mapped to the symbols N, A, B and C respectively. Starting from the lsb of the binary data frame to be transmitted,the system would then read every successive bit-pair to determine whether the corresponding transmitted CNS symbol is tobe an A, B, C or N and do the reverse mapping at the receiver to reconstruct the original binary string.[10]

A hybrid modulation scheme using FSK and ASK with non-coherent detection based receiver for theRBNSiZeComm protocol has been implemented and tested by Sinha k., et al.,using simulation in 2011. In RBNSiZeComm transmission protocolconsider that there is a run of k 1's, $k > 1$. Let i be the bit position for the first 1 in this run, $i \geq 0$ (bit position 0 refers to the least significant bit at the rightmost end). Let υ represent the value of this run of k 1's. Then,

$$\upsilon = 2^{i} + 2^{i+1} + 2^{i+2} + \ldots + 2^{k+i-1}$$

$$= 2^{k+i} - 2^{i} \quad (1)$$

In RBNS, equation (1) can be represented by a '1' at bit position $(k+i)$ and a $\overline{1}$ at bit position i, and all the intermediate 1's between them are converted to 0's.

It is observed that for a run of k 1's, $k > 1$, the savings in terms of the number of non-zero digits is $k-2$ and the number of non-zero digits remains unchanged for $k = 2$. Hence, when the transmitter switched off for 0 bit-values then the power consumption of the transmitter is less than that in energy based transmission (EbT) schemes [11].

Algorithm to Transmit RBNS Data

Step 1: Recode the n-bit binary data frame to its equivalent RBNS data frame using steps 1.1 and 1.2 stated below.

Step 1.1: Starting from the least significant bit (lsb) position, scan the string for a run of 1's of length > 1. A run of k 1's (k>1) starting from bit position i , is replaced by an equivalent representation consisting of a '1' at bitposition k + i and a $\overline{1}$ at bit position i with 0's in all intermediate bit positions.

Step 1.2: Every occurrence of the bit pattern $\overline{1}1$ in a string obtained after step 1.1, is replaced by the equivalent bit pattern $0\overline{1}$.

Step 2: Transmit the RBNS data frame obtained from step 1 above.

Let's see one example having binary string as 110111, consisting only one '0' trapped between runs of 1's. Using reduction rule 1.1, the string $10\overline{1}100\overline{1}$ is found. Afterwards applying reduction rule 1.2, as we get the pattern $\overline{1}1$, replace it by $0\overline{1}$, thus, we get string as $100\overline{1}00\overline{1}$. Thus resulting in a further reduction in the number of non-zero symbols to be transmitted is achieved.The receiver side algorithm to receive a RBNS data frame and convert it back tobinary involves executing the reverse process of Transmit RBN Data algorithm to serially convert the received digits 0, 1 or $\bar{1}$ into its binary equivalent representation for further processing by the different layers of the network stack.

In 2013 Jadhav G. et al., compare the two communication schemes namely RBNSiZeComm and TSS scheme using simulation.[12]

In 2014 Kanawade S.Y. et al. review the different types of data codingtechniques to save the energy of wireless sensor node whiletransmitting the data Viz. Communication through silence(CtS), RBNSiZeComm, VarBaTaC, ternary with silent symbol(TSS). Author conclude that RBNSiZeComm,CtS,

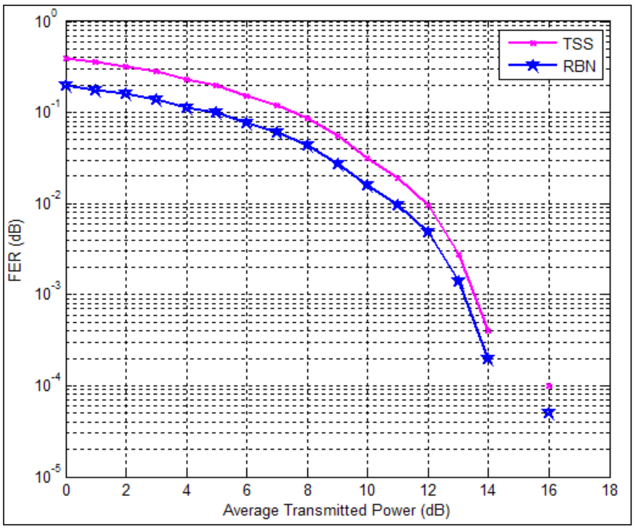

Figure 1.Average Transmitter Power in dB for the comparisons of TSS and RBNS for FER in dB from 10^0 to 10^{-5}[12]

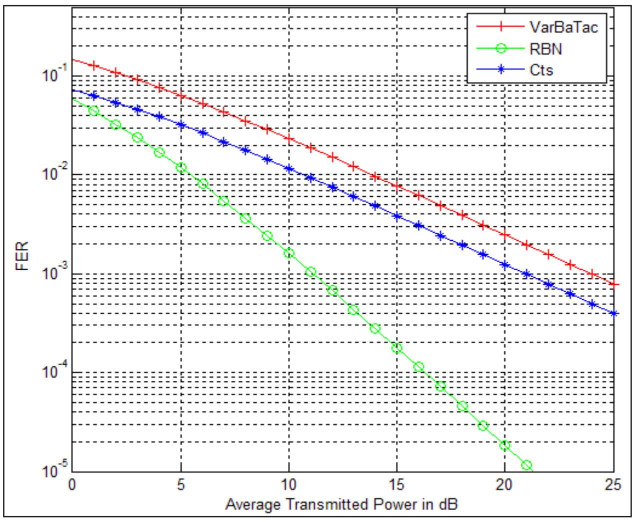

Figure 2.Average Transmitter Power in dB for the comparisons of VarBaTaC, CtS and RBNSfor FER in dB from 10^0 to 10^{-5}[19]

VarBaTaC saves the energy at the transmitter only anddoes not generates energy savings at the receiver. TSSgenerates energy savings simultaneously at the transmitter aswell as at the receiver. Also the transmission time of theRBNSiZeComm scheme is less than that of both CtS andVarBaTaC .[13]

Performance Comparison of RBNS with TSS

Fig. 1 compare the two communication schemes namely TSS and RBNSiZeComm scheme. The average transmitter power of both the schemes is almost same i.e. 14 dB.

Performance Comparison of RBNS with CtS and VarBaTaC

Fig.2 shows the comparison of three communication schemes Viz. VarBaTaC scheme, CtS and RBNSiZeComm scheme. From figure it is clearthat the average transmitter power of RBNSiZeComm scheme is approximately 21.3dBand for VarBaTaC and CtS it is 25 dB, which shows that the average transmitterpower required for RBNSiZeComm is approximately 3.7 dB less than VarBaTaC andCtS schemes.

In 2014 propose number system called the Tri-digit Fibonaccian Number System (TFNS), which providesasym-metric distribution inthe number of 0’s, 1’s and 2’s used in representing theall possible numbers, along with a sub-stantial reduction in the number of digits, so as tobring about significant energy savings in wireless communication systems. Also in theproposed TFNS, a pair of 2’s will never appear in a valid codeword. Thus, TFNS canbe used for variable length encoding of integers in data using a pair of 2’s as separatorsbetween consecutive integers in the data stream.[14]

In 2015, Tarle Mona., Kanawade S. proposed binary to gray codingtechnique for data transmission. In this coding scheme theinput data stream is converted into gray data instead ofsending as it is in binary form. This coded data containsreduced no. of 1’s as compared to binary data. Thus ourcommunication strategy requires energy expenditure fortransmitting only 1 and uses silent periods for transmitting 0.

Suppose a given binary data is represented by the n-bit binarydata, this binary data is converted into n-bit gray code. While converting into gray code firstly write the MSB bit of binary string as it is as a 1st bit of gray string, then 2nd bit by ex-oring the MSB and bit next to MSB from binary strings. This process is repeated till n-bits from binarystring gets finished.For example let the given binary string is 01100111. First number will be 0 as it is 1st bit of gray code (MSB from binarystring) then ex-or the 0 and 1(bit next to MSB) we get 1 asa 2nd bit, further next bit 1 ex-or with their next bit 1(from binary string) get 0. These steps are repeated. Finally number corresponding grey number as 01010100.

Thus thereduced number of 1's in gray string as compared to originalbinary string. Hence during transmission of grey stringtransmitter utilizes less energy as compared to transmission ofbinary string.[15]

In 2016 propose an energy-efficient scheme for the physical layer of the communication protocol using MRBNS encoding so as to get substantial energysavings in both transmitters and receivers of cognitive radio Networks (CRNs).

This proposed efficient communication scheme based on a novel source coding technique along with the idea of silent communication, so that the frequencies of occurrences of different symbols in the encoded message become very asymmetric. Keeping the symbol period with the highest frequency of occurrence as silent during transmission, Here a substantial savings of transmitter and receiver energies by using a hybrid FSK-ASK modulation/demodulation technique.[16]

Bhattacharya A. in 2016 proposed energy-efficient communication scheme for low-power wireless networks which is based on encoding the messages in a new number system, called the Quint Fibonacci number system (QFNS) followed by using a concept of Silent Communication. The proposed scheme employs a simple hybrid modulation/ demodulation technique using non-coherent FSK and ASK, which leads to the design of a low-power, low-cost wireless communication system that will particularly be suitable for remote/rural healthcare applications.[17]

In 2018 Majumder A. et al. proposed new technique termed as Compression with Multiple Null Symbols (CMNS) for energy-efficient communication in wireless sensor networks which is based on a novel source coding of multiple sensor data coupled with the use of silent communication strategy. The source coding technique exploits high temporal correlation between sensor data by first appropriately interleaving the bits of two consecutive sensor data values and then representing every two consecutive bits of this interleaved dual message by one of four symbol values so that the overall message length is reduced by a factor of two. After that, any occurrence of the same symbol value in consecutive positions of this string is replaced by a null symbol. The transmitter is kept silent during the periods of these null symbols following the strategy of silent communication to save transmitter energy. Researcher propose a hybrid modulation/ demodulation technique using non-coherent Frequency-Shift Keying (FSK) and Amplitude-Shift Keying (ASK) to implement this communication scheme.Simulation results shows that, CMNS provides transmitter energy savings ranging from 73.16%to 46.6% and receiver energy saving of 50% over conventional BFSK when compared with other existing scheme.[18]

In 2019 Sopara D. et al. presents compararative study of an energy efficient communication scheme called RBNSiZeComm with other silent zero communication scheme. After simulation and comparision, author observed that RBNSiZeComm scheme requires 1 dB less average power thanASK and FSK. Authoralso compare average transmitter power of RBNSiZeComm with othercommunication schemes like CtS, VarBaTaC and TSS. RBNSiZeComm needs 3.7 dB less transmitter power than CtS and VarBaTaCschemes while TSS and RBNSiZeComm schemes requires same transmitter power.[19]

Performance Analysis of Different Energy Efficient Communication Scheme

The traditional Communication strategy Energy based Transmission (EbT) involves energy expenditure for transmitting both 0 & 1bit values Hence for n bit data, energy expenditure is n* eb. While in CtS energy consumption is 2* eb (only start & stop signal) irrespective of the value being sent. but Cts suffers from the disadvantage of being exponential in time & lower throughput than that of EbT.

VarBaTaC generalizes both CtS and conventional binary coding based communications by using a variable coding base. The delay introduced by CtS is thus controllable by the tuning the coding base and can be reduced significantly.

Table 1.Comparison of Energy Savings Between Various Schemes [17]

Communication Energy Savings Scheme	Energy Savings at Transmitter	Energy Savings at Receiver
TSS (Ghosh et al., 2008)	20%	36.9%
RZE (Sinha et al., 2009)	35.2%	12.5%
CNS (Sinha et al., 2010)	30%	50%
RBNSiZeComm (Sinha et al., 2011)	53%	0%
TFNS (Sinha et al., 2014)	40.3%	36.9%
MRBNS (Bhattacharya et al., 2014)	53%	17.2%
QFNS (Bhattacharya et al., 2016)	39.6%	52%
CMNS (Majumder A. et al. 2018)	73.16%	50%

Unlike RBNSiZeComm, CtS and VarBaTaC, TSS simultaneously saves energy at both the transmitter and receiver due to shortening of the transmission duration.

Binary to gray conversion of data provide advantage of lessening in the total number 1's to betransmitted and hence total energy required for transmission of data will be lesser. But sometimes after conversion processgray data contains more number of 1's than binary data; this is the drawback of this technique.

From table 1 we can conclude that CNS outperforms TSS in saving energy at both the transmitter and the receiver side. It also show that while the transmitter energy savings by CNS is less than that of both RBNSiZeComm and the RZE scheme, it definitely performs significantly better than these schemes at saving energy at the receiver. As most WSNs tend to be multi-hop in nature, this fact makes CNS more suitable than either RBNSiZeComm, RZE or TSS for use in low power WSNs.

Table I also shows the numerical values of the energy savings generated by the various schemes at both the transmitter and the receiver, in comparison to a typical communication scheme utilizing BFSK with non-coherent detection. From these results we see that CMNS outperforms the MRBNS, CNS, TSS and RZE techniques in saving energy at the transmitter side. The results also show that while the receiver energy savings by CMNS is less than that in the Quint Fibonacci Number System (QFNS) scheme. As most wireless networks tend to be multi-hop in nature, this fact makes CMNS is more suitable than either MRBNS, RBNSiZeComm, RZE or TSS for use in low power wireless networks.

Conclusion

This paper presents comparison of energy efficient scheme for wireless sensor network. Author conclude thatneither CtS nor VarBaTaC generates energy savings at the receiver. TSS simultaneously saves energy at both the transmitter and receiver due to shortening of the transmission duration.CNS outperforms TSS in saving energy at both the transmitter and the receiver side generating significant savings inenergy at both the transmitter and the receiver. In RBNSiZeComm energy saving at transmitter is more as compared TSS, RZE and CNS but it does not generate energy saving at receiver. CMNS providesan improvement over all other energy efficient scheme like TSS, RZE, CNS, RBNSiZeComm, TFNS, MRBNS & QFNS in terms of energy saving at transmitter as well as receiver.

References

1. Zhu Y, Sivakumar R. Challenges: communication through silence in wireless sensor networks. In Proceedings of international conference on mobile computing and networking (MobiCom) 2005; 140–147.
2. Chen YP, Wang D., Zhang J. Variable-base tacit communication: a new energy efficient communication scheme for sensor networks. In Proceedings of 1st international conference on integrated internet ad hoc and sensor networks (intersense), Nice, France 2006.
3. Sinha K, Sinha B. P. A New Energy-Efficient Wireless Communication Technique using Redundant Radix Representation, Tech. Rep., Indian Stat. Inst., ISI/ACMU-07/01 2007.
4. Sinha K., Sinha BP. An energy efficient communication scheme for distributed computing applications in wireless sensor networks, in: Proc. Intl. Conf. on Distributed Computing and Internet Technologies, ICDCIT, in: LNCS 2008: 139-144.
5. Sinha K. A new energy efficient MAC protocol based on redundant radix for wireless networks, Proc. Recent Trends in Information Systems (RETIS), Calcutta, 2008; 167–172.
6. Ghosh RN, Sinha K, Sinha BP. TSS: An energy efficient communication scheme for low power wireless networks. In Proceedings of 27th IEEE international performance computing and communications conference (IPCCC), USA, 2008: 85–92.
7. Sinha K, Sinha BP. On the distribution of runs of ones in binary strings. Computers and Mathematics with Applications, Elsevier 2009; 58: 1816–1829.
8. Sinha K. An Energy Efficient Communication Scheme with Potential Application to Consumer and Personal Wireless Networks, 2009; IEEE, 978-1-4244-2309-5/09.
9. Sinha K. An energy efficient communication scheme for applications based on low power wireless networks, in: Proc. 6th IEEE Consumer Communications and Networking Conference, CCNC, Las Vegas, USA, Jan. 2009: 1-5.
10. Sinha K, Sinha B, Datta D. CNS: A New Energy Efficient Transmission Scheme for Wireless Sensor Networks, Springer-Verlag New York, Inc, 2010; 16(8): 2087-2104, ISSN:1572-8196.
11. Sinha K, Sinha B, Datta D. An Energy–Efficient Communication Scheme for Wireless Networks: A Redundant Radix-Based Approach, IEEE Transactions on Wireless Communication 2011; 10(2).
12. Jadhav G., Kanawade S., Gade A. (2013). RBNSiZeComm and TSS: An Energy Efficient Communication Schemes for Wireless Networks,Special Issue of *International Journal of Electronics, Communication & Soft Computing Science & Engineering,* (IJECSCSE) ISSN: 2277-9477.
13. Kanawade S, Tarle M, Patel S et al. Data Coding Techniques In WSN: A Review, *International Journal of Review in Electronics & Communication Engineering (IJRECE)* 2014; 5(2): 161-166.
14. Sinha K, Ghosh R, Sinha BP. A New Number System Using Alternate Fibonacci Numbers as the Positional

Weights with Some Engineering Applications, ICDCIT 2014, LNCS 8337, 2014; 164–175.
15. Mona T, Kanawade S. Enhance the lifetime of wireless sensor network using data coding technique IEEE International conference on information processing 2015, VIT, Pune.
16. Bhattacharya A. Sinha K, Datta D. MRBNS: A new energy-efficient communication scheme in low power wireless *International Journal of Sensor Networks*, Jan 1, 2016.
17. Bhattacharya A, Majumder P, Sinha K et al. An energy-efficient wireless communication scheme using Quint Fibonacci number system. *International Journal Communication Networks and Distributed Systems* 2016; 16(2): 140–161.
18. Majumder P. Dashy L. Sinha K et al. CMNS: An Energy-Efficient Communication Scheme for Wireless Sensor Networks, *IEEE International Conference on Advanced Networks and Telecommunications Systems* (ANTS) 2018, 978-1-5386-8134-3/18.
19. Sopara D, Kanawade S Y, Soni V. Silent Zero Communication (Rbnsizecomm) Protocol to Enhance the Lifetime of Wireless Sensor Network: A Comparative Study. i-manager's Journal on Wireless Communication Networks 2019; 7(4):x35-42 ISSN : 2320-2351.