Low Power ID Matching Wake-up Receiver for Wireless Sensor Networks

Vikas Kumar
Dept. of Electronics and Communication
Punjab Technical University
Kapurthala, Jalandhar, India

Jagjit Singh
Dept. of Electronics and Communication
DAVIET, Punjab Technical University
Kapurthala, Jalandhar, India

Arvind Kumar
Dept. of Electronics and Communication
National Institute of Technology
Kurukshetra, India

Abstract: Access points of wireless sensor network (WSN) consume lots of energy during data communication but huge power consumption has been observed during active listing in idle mode. There are lots of solutions available in the literature for addressed issue but among all available techniques, Wake-up receiver found most effective in term of power utilizations. It works on the basis of ID matching, paper present 16 bits ID matching Wake-up receiver and consumes only 42.38mW power. Proposed model can be efficiently implemented over very large sensor networks. Wake up receiver can be used in several applications of Wireless sensor networks along with main transceiver.

Keywords: wake-up receiver; wireless sensor network; low power; ID matching

I. INTRODUCTION

Wireless Sensor Networks (WSNs) draw attention of several researchers because many opportunities exist and lot of work need to be done. Wireless Sensor Networks having usage in many applications like Aviation, defense, medicament, industrial machinery observance, and overabundance of others. WSNs find peculiar trait sensors those can work in multidimensional environment and can be deployed in the uninhabited, ugly and adverse environment like battle field etc [1]. A sensor network must be competent enough for sensing the minutiae signal, execute signal processing on the detected signal and transmit it further wirelessly.

Several challenges exist for successful and reliable implementation of sensor nodes are as following:

- Intelligence should be added to sensors to make them capable to deal with issues such as network management, data integration and information interpretation [2].
- Security and reliability are also major challenge still require improvements [3].
- Quality of services (QoS) also remains one of the foremost vital areas in this [4]. Network management can be used for QoS but in addition to that data prioritization, clustering and data classification can also provide best optimal solution for problem
- In the domain of wireless sensor network resources i.e. security, data rate, power consumption and memory are available but with trade off although researcher has main aim to reduce power consumption in wireless sensor network. Communication and processing unit are very hungry for power consumption [5].
- Judicially utilization of power must be ensured because in most of the cases sensor are deployed in remote location where battery replacement is not frequently possible.

Hence, among all the discussed issues Low power consumption is most dominating which attracts attention of most of researchers [6]. In literature many solutions are implemented like duty cycle control, advancement in storage battery, advanced network protocol, power gating and scaling [7, 8]

However Wake up receiver for aforementioned purpose is the best among all [9]. Access points in WSN stay idle for most of time and they consume lots of power during idle mode [10]. So access points switched into sleep mode from active mode in spite of idle mode. In this way, the large portion of power can be saved [11]. Hence Wake-Up receivers represent a promising approach for minimizing the energy consumption in wireless communication environments to a greater extend.

Intelligent switching of nodes state can be effectively performed by Wake up receiver. To implement this design a novel addressing technique can be used and unique binary number will be assigned to every sensor node. Before active data transfer, transmitter send unique address to wake up receiver if that address is related to concerned network then explicit cluster comes into active state where addressed node resides. Efficient methodology has been used to locate particular sensor node and power can be saved using this technique.

Fake node calling can also be easily detected using designed receiver.

II. STATE OF ART

The idea of wake up receiver comes from free space optical communication (FSO) principle. The design and implementation of the FSO transceiver is done using electronic and optical components [12, 13]. Author justifies the use of a secondary, ultra low power, wake-up channel, with the implementation of Free Space Optical (FSO) transmission. The FSO channel is being used for wake up the receiver and high power radio can be used to transfer main data packets with high data rate.

RF energy detection and implementation of Wake-Up receiver result to low cost and run with low power consumption. Using RFID matching process nodes will only be switch states into active state at the time of active data communications [14, 15]. As per IEEE 802.15.4 standard,

before transmission of data sender activate the RFID tag and RFID reader card has been installed at other end on the interrupt pin of the node.

Laser has been used to send ID to unknown nodes for localisation of nodes in WSN [16]. Sensor node will be turned into active mode from sleep mode at time of active data communication. In this way transceiver can be migrated into deep sleep mode during no transmission data packet [17, 18]. A reliable communication can be achieved in range of few meters with low power consumption.

False triggering of node cannot be ignored during operation of Wake-Up receiver but it can be minimized using efficient design. Wake-Up receiver can be implemented using field-programmable gate array (FPGA) [19, 20]. Asynchronous mode of communication reduces many overheads and battery usage days are increased after using of Wake Up receiver. Verilog coding has been used for designing of transmitter and receiver [21]. Similarly advance receiver can also be designed for low power consumption using Verilog coding.

III. IMPLEMENTATION OF DESIGN

Power management becomes more important in case of applications using battery as power source. Reduction in power consumption causes to increase the life time of the network. Wake up receiver comes in front with many advantageous and reliable solutions. It works on the basis of ID matching where 16 bits ID matching Wake-up receiver has been proposed. The proposed design will be used to locate the sensor node and manage switching of cluster into different states like sleep mode, idle mode or active mode. Some mathematical hash function operations will be performed on address bits of sensor node for parameters extraction and these parameters will be matched with stored parameters in the memory. If it matches, start the active communication with found cluster.The proposed structure is multiphase processing and as follows

A. *Establish of wireless sensor networks*

The first phase includes establishment of the network. In this phase address of every node can be stored in memory. Within the process, unique ID of sensor can be store in memory but in our proposed architecture membership function value will be stored in spite of storing all sensors unique ID. Membership functions can be calculated after performing hash function and extraction of its values. Cluster number can be assigned to every sensor nodes based upon calculated membership functions. Details of mathematically function involved are given below

Sensor node ID is unique sequence of binary numbers and can be represented as

$$X = \{x1, x2, x3........xn\} \quad \text{where} \quad xn \in [0,1] \qquad (1)$$

Member function can be calculated with multiple hashing of nodes ID.

Hash function H[i] can be represented as

$$Hk[i] \quad \in f(X[i]) \quad \text{where} \quad i \in [0,1,2...m], \ I \qquad (2)$$

In proposed architecture k number of different hash function are used

$$f(X[i]) \quad \neq f(X[j]) \quad \text{Where i, j} \in [0, 1, 2...m], I \qquad (3)$$

Hash function value is its membership value and each value corresponding to individual sensor node ID is updated in memory.

Hence Cluster number can be calculated from the membership values

$$\text{Cluster No.} = \sum_{i=1}^{k} Hk[i]$$

Where k $\in$ I Cluster No. $\in$ [0, 1, 2, - - - - - -, km], I   (4)

In establish phase, n bits sensor node ID will be received and after calculating the membership value with the help of k number of hash function, cluster number can be assign to every sensors. Total number of cluster will be equal to K.m. Value of membership will be updated in memory to remember its states. A particular bit location in m-bit memory can be set more than once. If memory used is non volatile in nature then it can help us to remember the state of sensor node at power failure or in switch off mode.

B. *Power control mechanism*

Second and most important process is power control mechanism. This process describes how power can be saved with the help of used algorithm.

1. Once the network has been established and every node has been added successfully in respective clusters. Only detected cluster switching will performed without interfacing to other network.
2. False input and alarm can be easily detected and lots of power can be saved in this process.
3. Parallel processing has been used for further optimization, as 1st mismatch of membership value detected stop further calculation and false alarm has been reported for further action.

C. *Testing phase*

Last but not least phase is testing phase. In testing phase string of binary number has been transmitted from a transmitter. The test string ts, is hashed k- times using same hash function as used in first phase

$$Hk[i] \quad \in f(X[i]) \quad \text{where} \quad i \in [0,1,2...m], \ I \qquad (5)$$

All hash function results to membership value and matching from non volatile memory will be carried out.

$$f(X[i]) \quad \neq f(X[j]) \qquad (6)$$

Where i, j $\in$ [0, 1, 2…m], I

If all the values matches, resulting to true alarm signal for identified clusters concludes to request accepted and main communications can be started. As the 1st mismatch detected result to access denied and cluster will remain in deep sleep

mode. Hence in this way, in both cases either its match or mismatch wake up receiver, saves power and battery usage life will be increased.

IV. SIMULATION AND RESULTS

Wake up receiver has been implemented using Verilog. The schematic of design is shown in fig. 1. Schematic depicts three input pins and three output pins. The implemented design works in multiphase, depends upon input value of pin "add". If its value is 1 means receiver is in establishment phase and sensor nodes will be added to the network or if its value is 0 then it is in testing phase. "En_rst" is another input pin used to reset the receiver. "load_input" pin must be toggle every time and used to load input from external files.
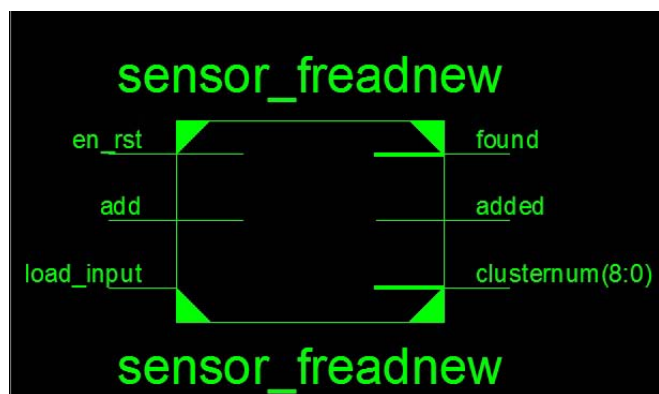
Figure1. Schematic of design

The internal structure of schematic is represented in fig. 2. Output pin "added" value "1" depicts, a new node is added into the network in establishment phase while pin "found" value"1" depicts successfully localization nodes within the network in the testing phase. Output pin "Cluternum" is used to describe the cluster number in both the phases. In establishing phase, sensor nodes will add to network and cluster number will be assigned to the node, based upon calculated value of membership function. In another phase, sensor ID will be received and it can be verified by fetching memory about the status of received ID. Instruction can be passed to cluster to come into the active stage and start active communications or it can also deny for start of communications if membership function not matched.
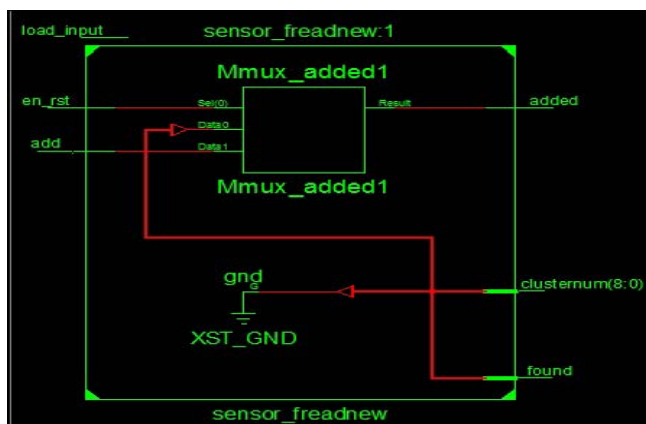

Figure2. Internal structure of schematic

There are some other signals involved within the design for successful implementation. Fig. 3 gives detailed information of other internal signal and their data types.

Figure3. Parameter of design with data types

Designed model is simulated with below mentioned parameters
n (sensor node ID length) = 16 bits
k (number of hash function) = 4
m (memory bits used) = 60 bits

Fig.4 shows waveform for new sensor node added into the network in establishing phase and cluster number is also assigned.

Figure4. Establishment phase

Fig. 5 shows for sensor accurately detected and instruction to start active communication has been given with found cluster number.

Figure5. Testing phase (found successful)

Fig. 6 shows waveform for the testing phase when called node does not exist in present network. All the pins output is at low voltage level because it shows the false input has been detected.

Figure6. Testing phase (found unsuccessful)

Hence in this way lots of power can be saved and prolong battery life is confirmed with large extend. Fig. 7 consists of result report of on chip power supply, Thermal summary and power consumption for the designs. ASIC design is using only 42.38 mW power.

Figure7. Result reports

V. CONCLUSION

A Wake-up receiver has been designed with the capability of using low power i.e. 42.38 mW. The proposed receiver is working on 16 bits ID matching system. Hence this model can be efficiently implemented over very large sensor networks. It can be used as transmitter and receiver model in all applications of Wireless sensor network where numbers of nodes are very large. This model will be more effective in term of power and security as compare to previous models. The researcher will found its better use in various applications where frequent charging of the battery is not possible. This model is also very beneficial in detecting false reception of address and power will also be saved in this process also. It will also reduce false triggering of the node with energy optimization.

VI. ACKNOWLEDGMENT

VII. REFERENCES

[1] M. VODEL, M. CASPAR, and W. HARDT, "Wake-Up-Receiver Concepts -Capabilities and Limitations, " Journal of networks, vol. 7, no. 1, pp 126-134, 2012.

[2] M. MAGNO, S. MARINKOVIC, D. BRUNELLI, and E. POPOVICI, "Smart Power Unit with Ultra Low Power Radio Trigger Capabilities for Wireless Sensor Networks, " DATE '12 Proceedings of the Conference on Design, Automation and Test in Europe, p. 75-80, 2012.

[3] O. STECKLINA, S. KORNEMANN, and M. METHFESSEL, "A secure wake-up scheme for low power wireless sensor nodes, " Collaboration Technologies and Systems (CTS) IEEE, p.279-286, ISBN 978-1-4799-5157-4, 2014.

[4] O. SAID, "Performance evaluation of WSN management system for QOS gurantee, " EURASIP Journal on Wireless Communications and Networking, pp. 1-18, 2015.

[5] I. DEMIRKOL, and C. ERSOY, "Wake-Up Receivers For Wireless Sensor Networks: Benefits And Challenges, " IEEE wireless Communications, pp.88-96, DOI-10.1145/1218556.1218562, 2009.

[6] A. PUGHAT, and V. Sharma, "A review on stochastic approach for dynamic power management in wireless sensor network, " Springer, Human-centric Computing and Information Sciences, pp. 1-14, 2015.

[7] M. A. SHAH, G. ABBAS, A. BASIT DOGAR, and Z. HALIM, "Scaling hierarchical clustering, " Springer Complex Adapt System Model, pp. 1-23, DOI: 10.1186/s40294-015-0011-6, 2015.

[8] D. ZHANG, X. WANG, X. SONG, T. ZHANG, and Y. ZHU Y, "A new clustering routing method based on PECE for WSN, " EURASIP Journal on Wireless Communications and Networking, pp. 1-13, DOI: 10.1186/s13638-015-0399-x, 2015.

[9] E. POPOVICI, M. MAGNO, S. MARINKOVIC, "Power Management Techniques for Wireless Sensor Networks, " Advances in Sensors and Interfaces (IWASI), pp. 194-198, 2013.

[10] S. TANG, H. Yomo, Y. Kondo and S. Obana, "Wake-up receiver for radio-on-demand wireless LANs, " EURASIP Journal on Wireless Communications and Networking, pp.1-13, DOI: 10.1186/1687-1499-2012-42, 2012.

[11] F. HUTU, A. KHOUMERI, G. VILLEMAUD, and J. GORCE , "A new wake-up radio architecture for wireless sensor network, " EURASIP Journal on Wireless Communications and Networking, pp.1-13, 2014.

[12] J. MATHEWS, M. BARNES, and D. ARVIND, "Low Power Free Space Optical Communication in Wireless Sensor Networks, " Euro micro Conference on Digital System Design, pp. 849-856, DOI:10.1109/DSD.2009.234, 2009..

[13] J. MATHEWS, M. BARNES, A.YOUNG, and D. ARVIND, "Low Power Wake-Up in Wireless Sensor Networks using Free Space Optical Communications, " International Conference on Sensor Technologies and Applications, pp. 257-261, 2010.

[14] O. BERDER, and O. SENTIEYS, "Power optimized hardware/software framework for wireless motes. In Proc. of the Workshop on Ultra-Low Power Sensor Networks, " Co-located with ARCS, pp. 229–233, 2010.

[15] N. SEYED, MAZLOUM, and O. EDFORS, "Performance Analysis and Energy Optimization of Wake-Up Receiver Schemes for Wireless Low-Power Applications, " IEEE Transaction on wireless communication, pp. 7050-7061, 2014

[16] K. KAUSHIK, D. MISHRA, D. SWADES, K. CHOWDHURY, and W. HEINZELMAN, "Low cost Wake-up Receiver for RF Energy harvesting Wireless Sensor Networks, " IEEE sensor, DOI: 10.1109/JSEN.2016.2574798, 2016.

[17] R. JURDAK, A. RUZZELLI, and G. HARE, "Multi-hop RFID Wake-up Radio: Design Evaluation and Energy Tradeoffs, " IEEE conference on Computer Communications and Networks, pp.1-8, DOI: 10.1109/ICCCN.2008.ECP.124, 2008.

[18] G. GAMM, M. SIPPEL, M. KOSTIC and L. REIND, "Low Power Wake-up Receiver for Wireless Sensor Nodes, " IEEE International Conference on Intelligent Sensors, Sensor Networks and Information Processing, pp.121-126, 2010.

[19] V. ROSELLO, and T. RIESGO, "Ultra Low Power FPGA-Based Architecture for Wake-up Radio in Wireless Sensor Networks, " Annual Conference on IEEE Industrial Electronics Society, pp. 3826-3831, 2011.

[20] A. URAIBY, K. YOSHIGOE, R. SEKER, and R. BABICEANU, "FPGA Implementation of Low-profile Wake-up Radio Receiver for Wireless Sensor Networks, " IEEE conference on consumer electronic, pp. 20-24, 2012.

[21] R. DIVYABHARATHI, P. SCHOLAR, C. HAKEEM, and A. MIAN, "Design and simulation of zigbee transmitter using verilog, " International Conference on Information Communication and Embedded Systems, pp.882-888, 2013

Author's Profile

Mr. Vikas Kumar born in 1985. He did his B.Tech (ECE) from Kurukshetra university in 2006 and completed his M.Tech (VLSI design, ECE department) with distinguishing from NIT Kurukshetra in 2010. He is pursuing Ph.D. (Electronic Engineering department) from IKPTU Jalandhar, Punjab. His research interests include Low power design and Wireless sensor network.

Dr. Jagjit Singh born in 1971 . He did his Ph.D. from PTU Jalandhar. He is a passionate researcher in the field of optical and wireless communication. He started his career as Lecturer in 1994 and is now working as Associate Professor in the department of electronics and communication engineering at DAV Institute of Engineering & Technology, Jalandhar. His current research area is multichannel high capacity optical links and wireless networks. He has more than 35 number of international research publications to his credit and has authored 04 books.

Dr. Arvind Kumar born in 1970. He has completed his B.Tech in 1996 from Allahabad University and M.Tech in 1999 from NIT Allahabad. He did his Ph.D. from NIT Kurukshetra, ECE department and working as Assistant Professor in the same department. His research interests include Wireless Communication, signal processing and communication system.