© 2017 IJEDR | Volume 5, Issue 3 | ISSN: 2321-9939

An Energy Efficient ASIC for Wireless Body Sensor Networks in Medical Applications

[1] *C Ram Kumar,*[2] *B Vijayalakshmi,*[3] *K Keerthana,* [4] *K Kiruthika*

[1]Assistant Professor,[2] Assistant Professor,[3,4] UG Student
[1,3,4] BME, Dr.N.G.P. Institute of Technology, Coimbatore, India
[2] ECE, Sri Ramakrishna Engineering College, Coimbatore, India

---

Abstract— **Wireless body sensor networks is a wireless network of wearable computing devices. These devices may be embedded inside the body or surface mounted on the body in a fixed position. An application specific integrated circuit (ASIC) is designed for wireless body sensor networks in medical applications. ASIC is an integrated circuit customized for a particular use rather than intended for general purpose. The Application specific integrated circuit designed is energy efficient and featured with work on demand protocol. This work on demand protocol is achieved by the use of a always-on passive RF receiver with an RF energy harvesting block. The energy efficiency is brought about by the use of low power microcontroller unit and power management unit. Apart from this the application specific integrated circuit also consists of sensor interfaces, communication ports controlling a wireless transceiver.**

IndexTerms— **ASIC, RF Receiver, WBSN and Medical Applications**

I. INTRODUCTION

Diabetes is a metabolic disorder in which the person has high blood glucose levels..It is estimated that over 382 million people throughout the world have diabetes. Therefore, it is very essential to determine the blood sugar level well before it causes adverse effects. The ASIC designed can be used to monitor blood glucose levels and provide necessary subsequent treatments. Recently, researchers are spending great efforts on the wireless body sensor networks (WBSNs) for medical applications, such as vital sign monitoring, the diagnose assistant and the drug delivery. In these applications, the master-slave protocol is commonly adopted to lower the system complexity and power consumption as well. A typical WBSN is usually composed of a portable device which serves as the master node for central control and a number of miniaturized sensor nodes placed around, on, or inside the human bodies that act as the slave nodes. Compared to the master node, the slave nodes have more stringent constraints in terms of power consumption and size limitation.

Typical WBSN slave sensor nodes can be used for biomedical information acquisition, signal pre-processing, data storage, and wireless transmission. This type of slave sensor node is called the sensing node. In addition, the function of sensor nodes can be expanded to medical treatments, such as drug delivery and nerve stimulating and this type of slave sensor node is called the stimulating node. One difference between the two types of nodes is that the functions of a sensing node are usually periodically performed, while the functions of a stimulating node can be either periodical or event driven.

The implemented ASIC has two standby modes. In the active standby mode, only an ultra-low-power (ULP) timer with a low-frequency clock generator is active and it periodically power ups the sensor node. In the passive standby mode, the whole sensor node is power silent, and a secondary passive RF receiver works as the supervisor circuit. The specifically designed passive RF receiver can harvest energy from the RF signals in the space which is transmitted by the master node that is not power critical, and hence, the passive standby mode consumes zero power ideally. The active standby mode can be used for the sensing and stimulating nodes. As a contrast, the passive standby mode can find its perfect use for the stimulating nodes, since the event-driven stimulating nodes can be woken up on demand without any response latency, while consuming zero power.

The ASIC has communication ports to control an off-chip ULP half-duplex transceiver which serves as the primary communication channel of information ex-changing and networking. The secondary passive receiver mentioned before can also provide the function of information exchanging, though the data rate is lower compared to the primary channel. In addition, a power-management unit (PMU) provides the different voltage levels needed, and the PMU is controlled by the MCU to offer several power modes in accordance with the communication modes.

II. WORK ON DEMAND WBSN

2.1 Sensing and Stimulating Nodes

In a WBSN, the sensing nodes and the stimulating nodes show quite different operation characteristics. A sensing node usually performs biomedical signal sensing and data transmission periodically. For example, a glucose detector wakes up and measures the blood sugar level every 5 min. Since most biomedical signals have a very low updating rate, the sensing nodes usually work in a manner of low duty cycle. A stimulating node feeds stimulus back to the human body whenever needed, such as the instant insulin injection when abnormally high blood sugar is detected in an automatic insulin pump with closed-loop control. A typical scenario of how the sensing nodes, the stimulating nodes, and the master node operate interactively in a WBSN is described as follows.

1) The sensing nodes wake up and sense the biomedical signals periodically.
2) Once the sensing nodes detect any abnormality, an emergency event is reported to the master node immediately.
3) The master node makes the decision accordingly, and wakes up the corresponding stimulating node if needed.
4) The stimulating node performs medical treatment as demanded by the master node.

In this typical scenario, it is clearly seen that sensing nodes are activated in a periodical way, while the simulating nodes work in an event-driven manner.

2.2 Work and Standby

Two states are defined for the WBSN slave nodes: 1) work and 2) standby. The slave node switches between the work state and the standby state. The jobs accomplished in the work state are signal sensing, data processing, and wireless communication. Conventionally, a low-power timer is utilized for the standby state. This timer periodically wakes up the WBSN slave nodes. The sensing nodes work well in this way since in medical applications, the sensing nodes usually perform signal sensing periodically. Since we are not sure what time the next drug delivery or stimulating operations will be as requested by the master node, the stimulating node has to be activated adequately frequently to listen to the master node. There lies the contradiction between maximizing the energy efficiency and minimizing the response delay for the stimulation nodes. The wake-up frequency directly affects the duty cycle ratio in that the slave node is in the work state. Hence, the necessity arises for a "work-on-demand" solution for WBSN slave nodes, especially for the stimulation nodes. This solution should provide high energy efficiency and short response latency simultaneously.

2.3 Work-on-Demand with a Secondary channel

The WBSN master node and slave nodes usually have a bi-directional communication channel to exchange information. Let us call it the primary channel. Conventionally, at the end of the standby state, the primary channel communication is started, and the slave nodes listen to the master node.In this paper, we propose a secondary communication channel in addition to the primary channel for the WBSN. The communication is one way, and the master node has a transmitter, while the slave nodes only have a passive receiver for this channel. This secondary channel has the following features:

1) Passive receiver in the slave node does not consume any current from its own battery; instead, the receiver has an energy harvesting block to convert the received RF signals to a dc power supply.
2) Passive receiver in the slave nodes is always ready to receive any emergency commands from the master node;
3) Transmitter in the master node transmits not only useful information but also energy to the slave nodes.

With the secondary channel, the master node can wake up the slave nodes in the standby state at any time if necessary. From the slave node side, the standby state does not consume any power (no timer) and the wake-up procedure does not require any energy (no active listening). It is clear that the secondary channel needs simplified modules at the receiver end (slave node).

2.4 Two Standby Modes

With the primary and secondary communication channels integrated altogether, the WBSN slave nodes can have two modes for the standby state: 1) the active standby mode and 2) the passive standby mode. In the active standby mode, the slave nodes use the primary channel to periodically listen to the commands from the master node. In the passive standby mode, the slave nodes only use the secondary channel for passive emergency listening. Standby mode II has much higher energy efficiency than standby mode II, in the cost of signal receiving sensitivity and communication distance.

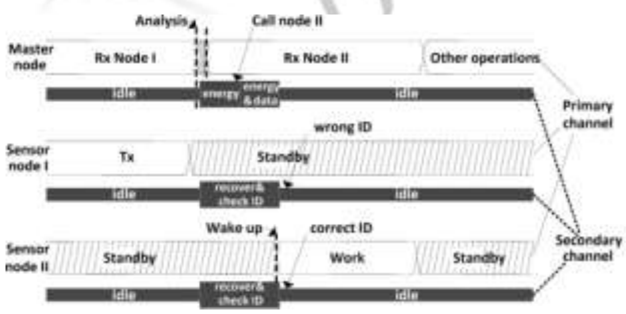

Fig 1: Typical scenario of WBSN: sensing and stimulating nodes.

The slave node I is a sensing node and sensor node II is a stimulating node. With the proposed architecture, sensor node I is configured to use the active standby mode, while sensor node II can be configured to use the passive standby mode in the standby state. For example, in blood glucose monitoring of diabetic patients, whenever abnormal blood sugar level is detected by the sensing node, the master node should give warnings and send commands to the stimulating node, then insulin is delivered by the stimulating node. The control procedures of the proposed WBSN protocol are listed as follows.

- Node I (configured to active standby mode) wakes up periodically to collect biomedical information data and transmits the data to the master node.
- The master node receives and analyzes the data from node I.

- If the master node finds some data abnormal, it needs to decide the necessary step.
- The master node transmits emergency command (containing node II's ID information) through the secondary channel. Note that node II is configured to passive standby mode.
- All of the slave nodes receive the emergency command including node I, but only node II responds after ID recognition.
- Node II wakes up immediately and performs the function as requested (e.g., driving the insulin pump, giving nerve stimulus, etc.).

High energy efficiency has been achieved for the WBSN described before, by utilizing the proposed two standby modes properly. Also, please note that the real-time work-on-demand capability has been achieved with the additional secondary passive channel.

III. ASIC ARCHITECTURE

Utilizing the passive RF receiver for the secondary channel, the always-on slave sensor nodes can listen passively to the master node, and can respond to the master node's request with a much shorter response time.

The function block diagram of a proposed WBSN sensor node is shown in figure. The sensor node can be divided into six major function blocks: 1) a digital core for controlling and processing; 2) a power-management unit; 3) an active bidirectional RF transceiver for data link; 4) a passive RF receiver for the work-on-demand capability; 5) a state/standby mode control block for energy-efficient operations; and 6) the sensing/stimulating devices for biomedical signal sensing and stimulating.

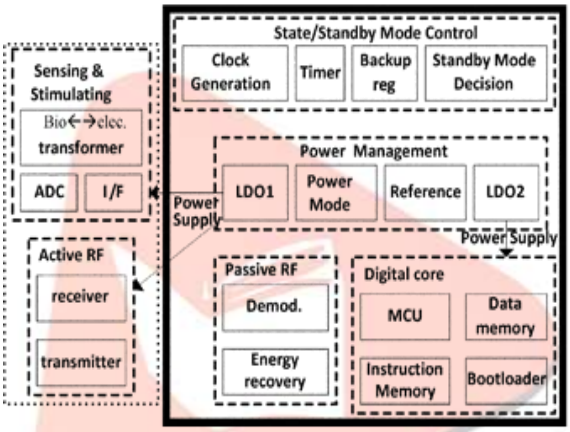

Fig 2: Function blocks of a slave sensor node

The digital core is composed of a main control unit (MCU), a boot-loader, instruction memory, and data memory. The power-management unit (PMU) is mainly composed of two low-dropout linear regulators which generate an analog VDD and a digital VDD, respectively. The state/standby mode control block contains the standby mode decision logic and an ULP timer for periodical wakeup. The passive RF receiver provides the function of RF signal receiving without quiescent current. The interfaces between the ASIC and the remaining function blocks are compatible with the common peripheral protocols, such as SPI, general-purpose parallel, etc.

3.1 Control Flow

The control flow of the slave sensor nodes in the proposed WBSN is shown in Fig. 4. With the control flow, the slave nodes can accomplish the sensing-processing-communicating-executing flow under supervision of the master node. The remote master node can also configure the slave nodes' states and modes through this control flow. The primary wireless communication channel for the data link adopts the half-duplex contention-based protocols. The up-link (from the slave node to the master node) is for biomedical information data transmission and the downlink (from the master to the slave) is for sensor-node configuration and stimulating commands. Forward error controlling (FEC) and automatic repeat request (ARQ) are utilized to ensure communication quality.

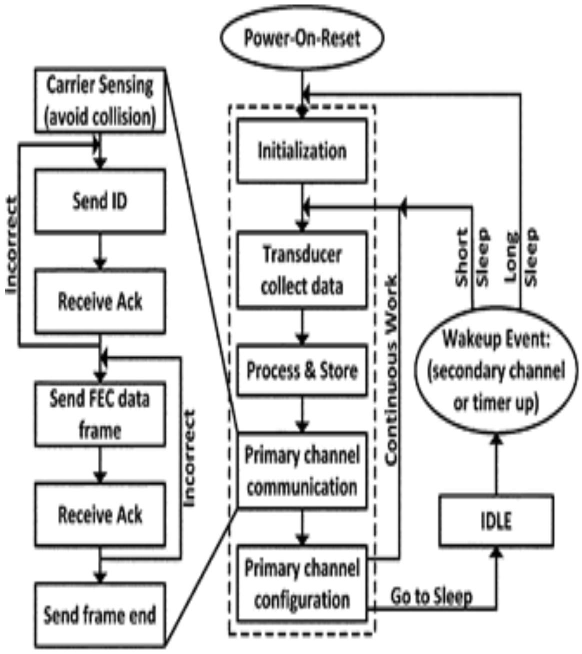

Fig 3: Control flow of slave nodes

In this control flow, the slave nodes can awake up from the standby state when triggered by two events: 1) a local timeout signal from the timer in the ASIC and 2) a remote signal from the master node, corresponding to the two standby modes. The standby mode of a slave node can be configured by the master node remotely, and the slave node can accept the wake-up trigger that matches its standby mode.

3.2 Power Management:

The proposed sensor node is powered by a 3-V battery power supply. The PMU converts the 3-V power supply into the voltages levels as needed by other function blocks. Two programmable linear regulators are integrated in the ASIC for this function. Specifically, the digital core is supplied by a 1.8-V supply generated by one regulator, and the other analog blocks used are the 2.5-V analog V_{DD} supplied by another regulator. Another function of power management is to enable/disable all of the function blocks (including the linear regulators) ac-cording to the state and standby mode control and the commands from the remote master node. The power-mode control logic is powered directly by the battery. It makes the decision whether and when the other modules should be switched ON/OFF. There are only a few flip-flops in this logic circuit that consume power only when the states change.

In the work state, the power-mode control logic in the PMU will shut down part of the function blocks if there is no need to turn them on, according to the presetting stored in the register bank or any setup command from the remote master node. Proper usage of this function provided by the ASIC will greatly help to improve the system power efficiency. In the standby state, almost all of the function blocks are disabled. For the active standby mode, only the ULP timer with a low-frequency clock generator is enabled, while in the passive standby mode, all of the circuit blocks are disabled except for the passive RF receiver listening to the master node power-silently.

IV. CONCLUSION

The standby power issue and the response latency in the WBSN have been inspected in this work, and an energy-efficient protocol with work-on-demand has been proposed for WBSN. Compared to the conventional structure, the proposed WBSN slave sensor node has a secondary wireless receiver. This secondary receiver has an energy harvesting block so that it does not consume any current from the sensor-node battery. Also, the secondary receiver is always on, which offers the sensor node the capability of real-time work-on-demand.

REFERENCES

[1]. X. Xie, G. Li, and X. Chen *et al.*, “A low-power digital IC design inside the wireless endoscopic capsule,” *IEEE J. Solid-State Circuit*, vol. 41, no. 11, pp. 2390–2400, Nov. 2006.

[2]. Banupriya, M., et al. "Remote Monitoring System for A Switchable Distribution Transformer by the Use of Wireless ZigBee Technology." *International Journal of New Trends in Electronics and Communication (IJNTEC-ISSN: 2347-7334)* 1.4 (2013): 47-49.

[3]. Vijayalakshmi, B. "Patient monitoring system using Wireless Sensor based Mesh Network." *Computing Communication & Networking Technologies (ICCCNT), 2012 Third International Conference on*. IEEE, 2012.

[4]. K. Yano, N. Sato, Y. Wakisaka, S. Tsuji, N. Ohkubo, M. Hayakawa, N. Hitachi, and K. Kokbunji, "Life thermoscope: Integrated microelectronics for visualizing hidden life rhythm," in *Proc. ISSCC Dig. Tech. Papers*, Feb. 2008, pp. 136–137.

[5]. Kumar, C. Ram, S. Karthik, and N. Karthikeyan. "Fairness Aware Probabilistic Algorithm with Rate Control and Congestion Avoidance in WSN." *Asian Journal of Information Technology* 15.11 (2016): 1851-1855.

[6]. A. C. Wong, D. McDonagh, and G. Kathiresan *et al*., "A 1V micropower system-on-chip for vital-sign monitoring in wireless body sensor networks," in *Proc. ISSCC Dig. Tech. Papers*, Feb. 2008, pp. 138–139.

[7]. Kumar, C. Ram, et al. "Improvement in Energy And Avoiding Packet Errors In TCP By CODA Mechanism." 2.1 (2017): 19-24

[8]. Vijayalakshmi, B., and C. Ram Kumar. "Applications of Embedded System in Cluster Testing." 1.1 (2012): 1-9.

[9]. Kumar, C. Ram, et al. "Improving Throughput and Energy Efficiency By Pctar Protocol In Wireless Sensor Network." 1.8(2016): 404-409.

[10]. Kumar, C. Ram, et al. "Vehicle Theft Alarm And Tracking The Location Using RFID & GPS." *Journal of Emerging Technology and Advanced Engineering (IJETAE)* 3.12 (2013): 525-528.

[11]. Punitha, R., et al. "Adoptive parent based framework for zigbee cluster tree networks." *International Journal of Engineering and Technical Research* (2014): 2321-0869.

[12]. Ramkumar, C., HR Pradeep Kumar, and S. Krishnaprasanth. "EAACM: Enhanced ACK Aware Clustering Mechanism for Energy Efficient and Secure Routing in Wireless Sensor Networks." 2.4 (2014): 53-62.

[13]. R. Dudde and T. Vering, "Advanced insulin infusion using a control loop (ADICOL) concept and realization of a control-loop application for the automated delivery of insulin," presented at the 4th Annu. IEEE Conf. Information Technology Applications in Biomedicine, Birmingham, U.K., 2003.

[14]. Abirami, A., et al.,"Enhancement of Satellite Image Resolution With Moving Objects"." *IOSR Journal of Electronics and Communication Engineering (IOSRJECE)* 4.6 (2013): 22-27.

[15]. Kumar, C. Ram, and M. Jennie Bharathi. "Enhancing Coding Aware Routing and Handling Link Failure in WSN." *Journal of Computer Applications (JCA)* 4.4 (2011): 2011.

[16]. Banupriya, R. Punitha, B. Vijayalakshmi, and M. C Ram Kumar. "Power Transmission Monitoring System Using Wireless Zigbee Technology." *Global Journal of Research In Engineering* 13.16 (2014).

[17]. Ramesh, Senior Engineer, E. E. E., and Igate Patni. "Train Ticketing System using Smart Card." International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering (IJIREEICE) 1.9 (2013): 491-496.

[18]. Vijayalakshmi, B., and C. Ram Kumar. "Transmission of Power to the Island Using HVDC."

[19]. Kumar, G. Aravinth, and M. Ramya. "Wedding of robots with agriculture." *Computing Communication & Networking Technologies (ICCCNT), 2012 Third International Conference on*. IEEE, 2012.