EFFECT OF HASH FUNCTION ON PERFORMANCE OF LOW POWER WAKE UP RECEIVER FOR WIRELESS SENSOR NETWORK

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ABSTRACT

Next generation network will consist of different types of wireless networks like WSN, Wi-Fi, WiMAX, UMTS, LTE and etc. Wireless Sensor Network (WSN) finds unique and special application as compared to the said networks because sensors are deployed in a very secret, awkward and hostile environment like battle field etc. Various wireless sensor nodes are interconnected and form a Wireless Sensor Network. Sensor nodes once deployed in a region, can't be repaired thus the power system deployed in the nodes becomes a major key issue i.e. how long its battery life can be utilised. Another major issue of WSN is to have a more secured network which is a function of hash keys. Increase usage of hash key means enhanced security but at the cost of power and area. Sensor systems must utilize the minimal possible energy while operating over secured and wide range of operating scenarios. In this paper, we have proposed a novel ID matching mechanism that uses a Bloom filter to realize wake-up wireless communication. Paper uses hash function for uniquely recognizing particular sensor- node- cluster among all clusters. Paper also shows the effect of number of hash functions on performance of wireless sensor node. The design and implementation of a wireless wake-up receiver module simulation reveals that proposed model consume 724nW dynamic power and with bloom filter, the proposed model consumes dynamic power 85% less than the consumption cited in "Takiguchi" model[1]. Dynamic power is further reduced by 10% when parallel processing is implemented. Finally paper provides a novel approach to save the dynamic power and subsequently increases the battery life of wireless sensor node and network as a whole.

KEYWORDS

Wireless sensor network (WSN), Low power, VLSI, Wake up receiver, Bloom filter

1. INTRODUCTION

In the next generation wireless communication systems viz. WPAN, ZIGBEE and specifically WSN, there is a great need to reduce the power consumption so that the network components can be used for a longer duration. The design of a WSN depends significantly on the application, and it must consider factors such as the environment, the applications design objectives, cost, hardware, and system constraints. Another major issue of WSN is to have a more secured network which is a function of hash keys. Increased usage of hash key means enhanced security in term of recognizing sensor- node-cluster with very less false probability but at the cost of power and area. So aim of paper is to give appropriate security to network but with low power consumed by wireless sensor network and corresponding node because dynamic power is also important factor of consideration.

A sensor network system consisting of a large number of small sensors with low power can be an effective tool for collection and integration of data by each sensor in a variety of environments. The collected data by each sensor node is communicated through the network to

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a single base station that uses all collected data to determine properties of the data. Clustering sensors into groups, yields that sensors communicate information only to cluster heads and then the cluster heads communicate the aggregated information to the base station.[18]

Wireless Sensor Network could contain hundreds of sensors that collect and some cases pre-process data before it is sent to central node for final processing. In the most cases sensors are deployed to remote location without capability to replace battery. This means that one of the key elements for distributed sensors is long lifetime covering both reliability and energy efficiency because the battery limits lifetime of the sensors.

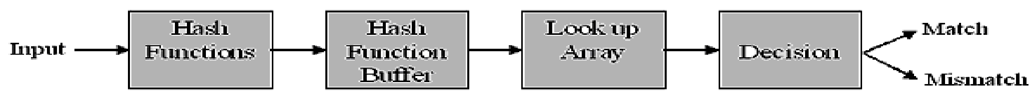


Figure 1.Block Diagram

Wake-up wireless communication technology is a promising candidate for reducing power consumption during idle listening. To realize wake-up wireless communication, here we propose a novel ID matching mechanism that uses a Bloom filter. A Bloom Filter is a data structure that stores a given set of signatures by computing multiple hash functions on each member of the set and testing strings for membership of that set. A Bloom Filter is a data structure that stores a given set of signatures by computing multiple hash functions on each member of the set and testing strings for membership of that set.[3] It consists of a set of hash functions, a hash function buffer to store hash results temporarily, a look up array to signify hash values and a decision component made of an AND to test the membership of testing string as shown in Fig.1

2. MOTIVATION

Wireless Sensor Networks (WSNs) have attracted the attention of many researchers. Wireless Sensor Networks (WSNs) are used for various applications such as habitat monitoring, automation, agriculture, and security. Since numerous sensors are usually deployed on remote and inaccessible places, the deployment and maintenance should be easy and scalable Wireless sensor network consists of large number of small nodes. The nodes then sense environmental changes and report them to other nodes over flexible network architecture. Sensor nodes are great for deployment in hostile environments or over large geographical areas.

Now days the power has become one of the foremost issues in the design of any system. It doesn't matter at which scale you are designing a circuit, but there should be a reduction in power consumption. And also there is a direct correspondence between power dissipation and system performance/ functionality, battery life, cost, and size.

A hand-held device, for example Mobile phone, Palmtop etc. must be small. As any system working with supply voltage produces heat and it require huge battery if it has number of functions. And a huge amount of heat can burn the IC or the system. There is, therefore, no room/space for a fan for cooling the system or a large battery for delivering a supply voltage. So it should be low power consumed device and its cost should be less.

In case of computers there is a direct relationship between area, cost and power. Firstly, there is the electricity bill from the computers. Secondly, there is the electricity bill and maintenance for the air conditioning system, which has to remove the heat due to power dissipation. Third is, the area required to place the air condition. In other words, the more Power a system burns, the more space it must occupy.

Power is as important as Performance

Current short-range wireless modules consume most power in idle listening for receiving packets. To reduce the power consumption for energy-constrained applications (e.g., wireless sensor networks) many energy-efficient MAC protocols have been designed to reduce the idle listening time.

Wake-up wireless communication can be used as a novel energy efficient communication scheme. The wake-up wireless module expends only several tens of microwatts in idle listening, while the data communication module remains in sleep mode, thereby minimizing its energy consumption.

3. Literature survey

The wireless revolution has come upon us swiftly and powerfully. Today one of the most challenging areas for VLSI designers is VLSI circuit and system design for wireless applications. The increasing use of portable computing and wireless communication systems makes power dissipation a major concern in low power circuit designs. Therefore, accurate power estimation tools are of critical importance. As VLSI circuits continue to grow and technologies evolve, the level of integration is increased and higher clock speeds are achieved. Higher clock speeds, increased levels of integration and technology scaling are causing an increase in power consumption. As a result, low power consumption is becoming a critical issue for modern VLSI circuits. Furthermore, power dissipation, dynamic and static, has become a limiting factor for transistor performance, long term device reliability, and increasing integration.

Researchers have focused on Wireless Sensor challenges that have limited resource capabilities of the hardware i.e. memory, processing power, bandwidth and energy deposits.

We focused on to energy deposits because

- Wireless sensor networks are battery driven
- In most cases sensors are deployed to remote location without capability to replace battery
- Reducing power means increasing life time of WSN

In the past, the major concerns of the VLSI designer were area, performance, cost and reliability; power consideration was mostly of only secondary importance.

In recent years, however, this has begun to change and, increasingly, power is being given comparable weight to area and speed considerations. Several factors have contributed to this trend. Perhaps the primary driving factor has been the remarkable success and growth of the class of personal computing devices (portable desktops, audio- and video-based multimedia products) and wireless communications systems (personal digital assistants and personal communicators) which demand high-speed computation and complex functionality with low power consumption.

Average power consumption is a critical design concern. In the absence of low-power design techniques, current and future portable devices will suffer from either very short battery life or very heavy battery pack. And the heat produced by huge server largely affects the surrounding environment

3.1 Dynamic Power Dissipation

As dynamic power consumption is due to charging and discharging of load capacitances, when transistors switch from ON to OFF and OFF to ON position and is given by [13]

$$PD=1/2fCV^2 \tag{1}$$

Where C= average total on-chip capacitance switched per cycle

The one cycle involves a rising and falling output. In the case of rising output, charge $Q=CV_{DD}$ is required to charge the load capacitance. In case of falling output the stored charge is dumped to GND through load capacitance. This repeats T*fsw times over an interval of T. Therefore the dynamic power is given by the equation as

$$\text{Dynamic Power (PD)} = C\ V_{DD}^2\ fsw \tag{2}$$

Let $f_{sw}=\alpha f$, where α is the activity factor and its value depends upon the switching transitions per cycle.

Thus dynamic power should increase as we increase the No. of hash function due to growth design. So α and C will increase result in increase dynamic power. Also as we decrease the frequency dynamic power decreases according to equation above. Dynamic power also give improved result if use parallel processing technique in designing the wake up receiver.

3.2 Number of cell

Technology library has some inbuilt cells. So cells used from technology to map the design are increasing as the number of hash function increasing.

3.3 Area

Here we discussed two types of area i.e. combinational area and non combinational area. Sum of these two is total area. Combinational area is the area required in micro meter used to map combinational part of design similarly non combinational area is the area required in micrometer to map non combinational part of design. As we increased the number of hash function area required should increase accordingly.

Conventional low-power design techniques and hardware architectures only provide point solutions which are insufficient for these high energy-constrained systems. Energy optimisation, in the case of sensor networks, is much more complex, since it involves not only reducing the energy consumption of a single sensor node but also maximizing the lifetime of an entire network. Sensor node should consume power only when it participates in communication otherwise remain in sleep mode. It can be done by wake up receiver

A Bloom filter is both a space and time efficient data structure for solving the set membership problem. Bloom filters were first proposed by B. Bloom in 1970 and were originally popular in database applications [22]. Universal hardware hash function was purposed by JL Carter and M.Wegman in 1978[21]. A performance study of Hashing Functions for Hardware Applications was done by M.Ramakrishna, E.Fu, and E.Bluahcekapili in 1994[20] and concluded that universal hash function is more efficient hash function for Bloom Filter. Architecture of Bloom Filter was first purposed by S.Dharmapurikar and P.Krishnamurthy in 2004[11]. Pipelined architecture of Bloom Filter was also studied by I. Kaya in 2006 and concluded that power consumption can be decreased up to 40% by pipelining but latency increases by little amount [8,9,10]. Michael Paynter and Taskin Kocak proposed Fully Pipelined architecture in 2008 [3]. Takiguchi and Saruwatari proposed a wake up receiver for wireless sensor network by which power consumption can be reduced up to 85% in 2009 [1].

4. Proposed design

Decoder will receive signal from antenna and convert it into string of 0 and 1 which is ID for individual sensor node to whom transmitter want to establish communication. The output of decoder we assume directly for our design and all results have been calculated for same ID so that we can compare them and switching activity (α) factor will remain same.

In ID matching using bloom filter block, we perform hash function K times. So it generates K number which will update/fetch data from memory. Initially all locations of memory are set to 0

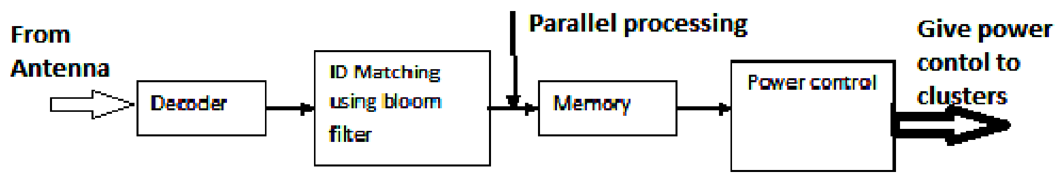


Figure 2: Proposed Receiver Design

We also used the parallel processing mechanism to optimise the resource more aggressively. Instead of performing all K hash functions first and then checking it from memory, we performed 1 hash function at a time and then checking it from memory i.e. we confirmed mismatch moment 1st zero bit is detected. Hence we don't require any further hash function calculation.

Proposed receiver has mainly two phases

(1) Cluster Design (Establish the network)
(2) Power control (Cluster)

4.1 Cluster Design (Establish the network)

- n bits code have been decoded by decoder, particular to sensor node and perform k times hash function with each hash function having n number
- It will generate k numbers (less than and equal to m) and set 1 to each k location in memory
- Add all the k number it will give the cluster number where particular node has been placed
- Total number of cluster will be equal to K.m

4.2 Power control (Cluster)

- After establishing network once, we can tell which cluster to turn on after performing hash function , all other clusters will remain in sleep mode
- Without giving power to any node, with the help of proposed receiver we can tell that node is present in our network or not
- We can also perform parallel processing for further optimising power
- Give mismatch as 1st 0, obtain from memory

4.3 BLOOM FILTER

Two basic operations are defined for Bloom Filter. First is programming for programming the look up array using hash functions of strings in data set and second is testing for checking the membership of test string.

4.3.1 Programming

Bloom Filter represents the set of n-signatures X= {X1, X2, X3…..… Xn} in an m-bit array. The elements in this array are set to '0' before programming. Each signature is of b bits and is hashed k-times by independent hash functions H1, H2, H3………Hk. It is assumed that each hash function maps uniformly to a random number in range {0, 1, 2……..m-1} where m defines the number of bits in look up array. The random number describing hash function value indicates a bit location in m-bit look up array, which is then set to '1'. A particular bit location in m-bit look up array can be set to 1 more than once [1, 8, 9].

4.3.2. Hash Function

A class of universal hash functions described here found to be suitable for hardware implementation. Following is a description of how this hash matrix is calculated

Given dataset of inputs

$$X= \{X1, X2, X3 \ldots\ldots\ldots Xn\} \tag{3}$$

Each input is of b bits

$$Xj = \{x1, x2, x3 \ldots\ldots\ldots\ldots xb\} \tag{4}$$

ith hash function over string Xj is given in eqn.5

$$Hi(Xj) = di.\ x1 \wedge di.\ x2 \wedge \ldots\ldots\ldots\ldots\ldots \wedge dib.\ xb \tag{5}$$

Hi(Xj) is the ith hash function of jth input string of input set. dij is a random coefficient ranging 1 to m. xj's are the bits in particular input string, where '.' is a bitwise AND operator,[3] i.e.

$$d_{ij} . x_i = \begin{cases} d_{ij}, & if \quad x_i = 1 \\ 0, & otherwise \end{cases} \tag{6}$$

'^' is a bitwise XOR operator. And m must be a power of 2 as shown in eqn.5

4.3.3. Testing

In testing phase, a string is tested for membership of programmed Bloom Filter. The test string is hashed K times as before. If all the hash values point to the bit locations that are set to '1' then this indicates that test string may be member of the set with a certain probability which is called as match. If any one of the hash values points to a bit location that is set to '0' then the test string is definitely not a member of the set and is called as mismatch.

5. Result and discussion

Results are obtained for wake up receiver with and without parallel processing using the following simulator:

- Xilinx –ISE (Model Sim)
- Design compiler (Synopsys)

System configuration

- Technology library (lsi_10k.db)
- Frequency (25Mhz and12.5Mhz)
- Operating condition WCCOM (Temperature 70C, Voltage 4.75volts)
- Number of decoded bits, n=16
- Number of hash function, k= 1 to 6
- Max. value of hash function, m=31
- Number of bits present in hash function, b =16

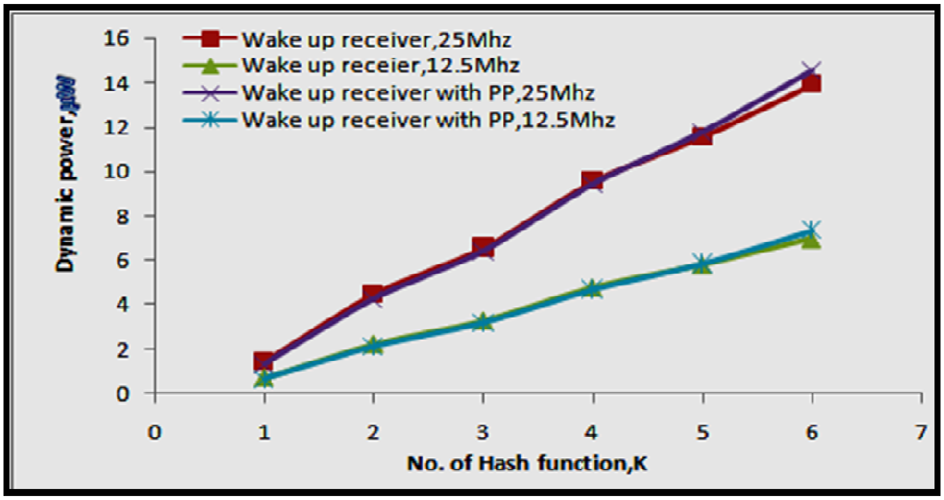


Figure 3: Dynamic Power Vs No. of hash fun.

Analysis

- Dynamic power increases with increase in number of hash function , K
- Dynamic power also decreases with decrease in frequency
- Wake up receiver with parallel processing consume less dynamic power than wake up receiver for same frequency.

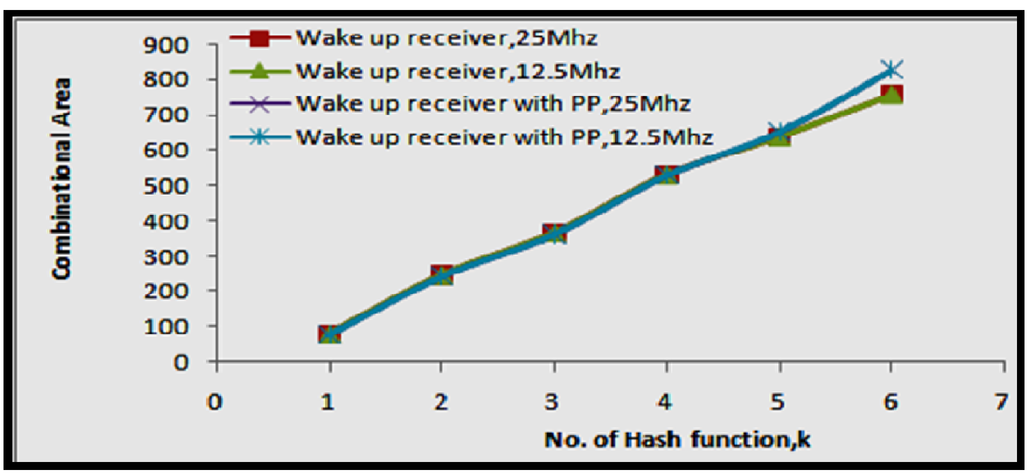
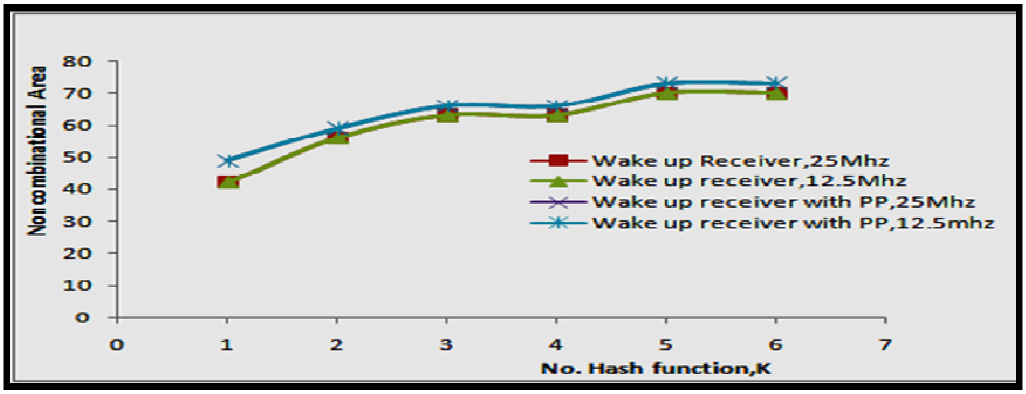


Figure 4: Combinational Area Vs No. of hash fun.



. Figure 5: Non Combinational Area Vs No. of hash fun.

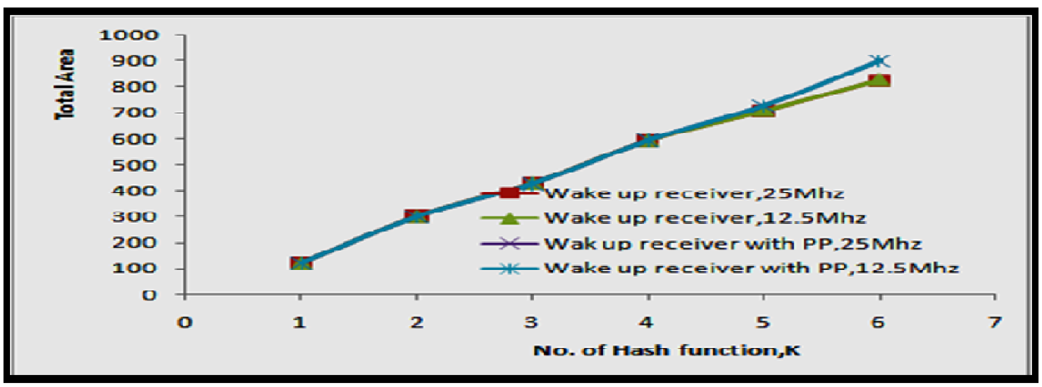


Figure 6: Total Area Vs No. of hash fun.

Analysis

- Combinational, Non Combinational and Total Area increase with increase in no. of hash function , K

6. Conclusion and Scope of the work

Wake up receiver model consumes less dynamic power i.e. 80% less than wake up receiver without bloom filter.[3] In case of wake up receiver with bloom filter, the proposed model consumes 85% less dynamic power than the consumption cited in “Takiguchi” model.[1] Design of receiver (using parallel processing) saves dynamic power more than 10%. As we increase the number of hash functions the network becomes more secure and trustworthy but at the cost of power, area and time. Though Combinational area, non combinational area and total area increases with increase in number of hash function.

The proposed model for synchronous wake up receiver can be extended to asynchronous wake up receiver for power optimisation. Voltage gating can also be implemented to reduce power consumption by wireless sensor network. Sensor code when processes from transmitter to receiver can provide cryptographic protection and can use any coding technique to make wireless sensor network more secure and trustworthy.

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