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High-resolution, Low-power Time Synchronization

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Abstract- Virtual High-Resolution Time, an energy conserving technique which is used to reduce the Micro Controller Units power consumption in low duty cycle. The power consumption which is highly correlated to the time resolution of the system is decided by the frequency of the Timer Interrupt Request. Therefore to support the events scheduling we utilize a high resolution time in active periods of sensor nodes and a low resolution time in sleep periods of the sensor nodes. We can change the resolution modes from high to low by carefully switching the time resolution and thereby there will be a cut down of power consumption up to 45%.

Index Terms: Wireless sensor network, energy efficiency, time resolution, low duty cycle.

I.INTRODUCTION

Wireless communication is known as collecting data or information from a particular area or object and transferring it to another area or object through which an observer can observe.Generally network is used to transmit. In order to communicate through wireless medium Wireless sensor networks are used. These Sensor Networks are composed of a large number of sensor nodes. Wireless sensor network sometimes called wireless sensor and actuator networks are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. Many WSNs are used for remote monitoring tasks, therefore need to be battery-powered and operate continuously for a long period of time. One of the most bottlenecks of wireless sensor networks is the energy issue [1]. Since the power consumption of Radio Frequency is much higher than other parts of sensor node, most works focused on radio frequency. By using synchronous and asynchronous [2] protocols the duty cycle of the sensor nodes as low as 0.2%.

By reducing the duty cycle of a sensor node, the average power consumption of RF can be reduced. Comparing with the other parts of sensor node except RF, Micro Controller Unit (MCU) is typically the major part of power consumption. In order to reduce the power consumption of micro controller unit, temporarily suspend its operation and switch into a low power state. Virtual High-resolution Time (VHT) is provide [4] both low-power and high-resolution time synchronization by using two clocks.

The contribution of this paper is to dedicate the relationship between the MCU power consumption and the time resolution, since the power consumption of a micro controller unit is more when compared to other parts of the sensor node and it is highly correlated to the time resolution of the operating system. Because in working condition MCU is frequently interrupted by the timer interrupt requests from hardware clock to count the software timer for event scheduling and hence it consumes more energy. In order to reduce this we use clocks: one slow (low power) and one fast (high resolution).

II. Power Consumption of Micro Controller Unit

Microcontroller unit is a small computer on a single integrated circuit. It is also known as system on a chip. A microcontroller consists of one or more

procesor units along with memory and programmable peripherals. With the help of duty-cycles of the sensor nodes we can analyze the power consumption of MCU. The power consumption of the MCU is measured by the current draw of MCU with voltage power supply of 3 volts. When the system is in sleep state, most of the power consumption is contributed by MCU. With different time resolutions of operating system, the current draws of MCU is varied when the node is in sleep mode which is determined by the frequency of hardware timer IRQ.

Micro controllers must provide real-time response to events in the embedded system they are controlling. When certain events occur, an interrupt system can signal the processor to suspend the current processing event and to begin the interrupt service routine which is also known as interrupt handler. Since power consumption is important aas in battery devices, interrupts may also wake a microcontroller from a low-power sleep state where the processor is halted until required to do something by a peripheral event.

The power consumption of MCU can be calculated using below equation:

$$P_{base} = P_{kernel} + E_{timer} . f_{IRQ} \quad (1)$$

where P_{base} stands for the baseline power consumption of MCU, P_{kernel} stands for the power consumption of the kernel of MCU in stand-by mode, E_{timer} stands for the energy consumption of running the interrupt handler program to respond the IRQ from hardware timer, f_{IRQ} stands for the frequency of timer IRQ.

The time resolution of the operating system is determined by the configuration of the frequency of hardware timer IRQ. MCU needs to be in active state frequently to process timer IRQ, when the node is in sleep state, in order to count the value of software timer and query the condition of related events. When the counting is finished for the present IRQ and further IRQs were not yet received then MCU can go back to the stand-by mode. Hence we can say that when the time resolution becomes higher, the frequency of running IRQ handler increases linearly which will consume more power of MCU.

Since the sensor node usually need high accurate synchronization, efficient energy communication and timely event responding a high time resolution is needed when it is in active period. If the sensor node is in sleep mode, high time resolution causes a significant increase of MCU power consumption, which will accounts for a larger proportion in the total power budget when the duty cycle becomes lower.

(A)Virtual High-resolution Time:

A sensor periodically alternates between sleep state and active state whereas MCU operates two resolution modes namely High Resolution mode (HR) and Low Resolution mode (LR). When the MCU is in active state it receives IRQs such that it has to schedule the events and when it is the sleep period, without protocol-related events a low resolution could be used. The duration of High Resolution period is however little longer when compared with the Low Resolution period.

(B)Switch Mode:

In the virtual high time resolution the switch is from low resolution to high resolution. Ideally, MCU will receive a timer interrupt request at the right moment which is denoted as $T_{0.}$ Due to the clock drift of hardware timer, previous IRQ handler is running at the time of T_1-$T_{LR.}$ Then the hardware timer sets the next interrupt request as $T_{1.}$ When the MCU receives the actual interrupt request T1 which is much later than the starting time of the active period causes missing of incoming packets or additional idle listening due to asynchronous wake-up of coordinated nodes.

Due to this reason the maximum delay of the active period could be $T_{LR.}$ When the low resolution is large there will be serious problems in communication services and time sensitive events. In order to prevent this drawback we should switch the mode to high resolution called as transitional stage in advance to prepare for the active period. By this the time accuracy of events scheduling is improved greatly.

III. Evaluation

(A)Experimental Setup

Time Division Multiple Access (TDMA) is incorporated in Virtual High resolution time in order to evaluate the effect of it. When the node is in the active period, time slots are assigned to each one of it for beacon broadcast and data collection. If transmitter or receiver process is completed, transceiver will be turned off. Oscilloscope or any digital display is used calculate the current draw in active period to measure the voltage drop across a 10ohm resistor using a current meter. Thus we can obtain the actual duration of both active period and sleep period through the measured data and can calculate the average power consumption. The default parameters of evaluation is shown in the below table.

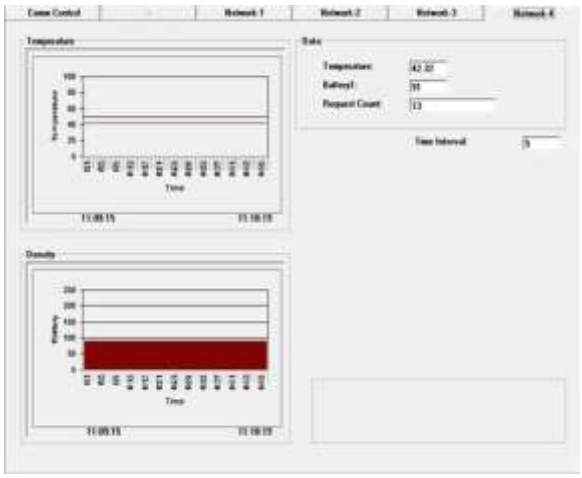
The experimental setup was given in images as below figures.

(B)Experimental Results

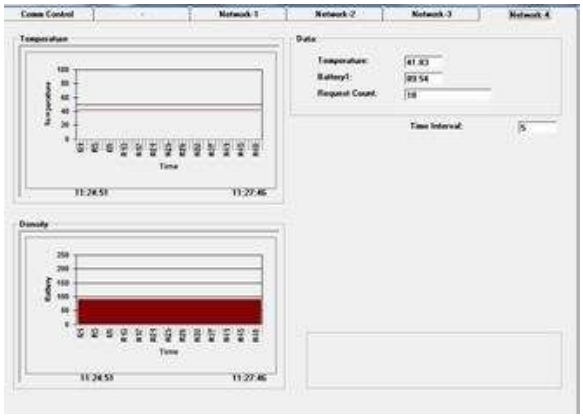
Without this virtual resolution time, the power consumption of micro controller unit is even higher than radio frequency when the time resolution is 1ms, since MCU has to respond frequently to all the interrupts all the time. This consumption is reduced when transition time (T_R) is set to 10ms. However, by this the power consumption of radio frequency increases. When the resolution is reduced leads to extra power consumption. In order to overcome this problem tunable time resolution is adapted since it does not increase the power consumption of radio frequency as it enables timely events response in active periods. Meanwhile, it can further cut down the power consumption of MCU by using optimized resolution.

The experimental results of the virtual high resolution time in both normal mode and by changing the clock we can get in TTR mode as shown.

The output we get by using the virtual high resolution project in normal mode as shown in the below figure.



By changing the clock resolution in to virtual time resolution the output is shown as



IV. Conclusion

In this paper, with the use of virtual resolution time the power consumption of MCU can be reduced in low duty cycle sensor nodes. It can dynamically change the resolution time and carefully switch to different resolution modes which maximize the energy efficiency and meet the requirements of scheduling by responding to the IRQs timely.

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