

Evaluation of Energy Efficient Medium Access Control (MAC) Protocol for Data-Intensive Sensor Networks

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Abstract. Data-Intensive Sensor Networks (DISNs) are sensor networks where large amount of different types of sensory data are sensed from physical environment and accessed by multiple users through networks such as the Internet. In such scenarios, networks are under heavy load and the role of an energy efficient medium access control (MAC)⁹ becomes more significant than a typical wireless sensor network due to energy constraints. Rather than evaluating MAC protocols using typical metrics such as comparing energy consumption among different MAC protocols, this paper compares different radio devices impacting on battery life, finding which radio device is suitable for DISNs. In experiments, two radio devices RF230 and CC2420 are compared, showing RF230 is more energy efficient and suitable for DISNs.

1. Introduction

The wireless sensor network (WSN) applications are becoming more popular and deployed in various fields such as habitat and environmental monitoring [1], and patient monitoring and tracking in the hospitals [2]. Data-Intensive Sensor Networks (DISNs) are enhancement of such typical WSNs applications. DISNs enable large amount of different types of sensory data to be generated and accessed simultaneously. Take patient monitoring in a hospital for example, a life-critical patient may carry more than one sensor devices such as a blood pressure sensor, a sensor for monitoring heart rate, a thermometer sensor. Those different types of sensors are also accessed and viewed by doctors, nurses, patient's family and researchers. Intuitively, the more data is generated and accessed, the more energy is consumed and lifetime of WSNs is shortened. Therefore, the issue of energy consumption in DISNs becomes more significant comparing to a typical WSN application. Particularly, energy efficient medium access control (MAC) protocols is the critical part. Unlike the devices in Internet, WSNs have many constraints such as wireless medium, memory, battery-powered, and bandwidth.

⁹ MAC provides addressing and channel access control mechanisms so that multiple nodes can communicate.

Consequently, it is very difficult to process large amount of data comparing to Internet.

In a typical WSNs application, extensive researches have been done about the energy efficient MAC protocols [3] [4] with various typical metrics such as sampling interval¹⁰, duty cycle¹¹, and energy consumption among different MAC protocols. These are important metrics in order to improve energy efficient protocols; however, since DISNs application absolutely consumes more energy than typical WSNs application, evaluating these metrics are not enough and finding other metrics which contributes on reducing energy consumption are necessary. In this paper, instead of comparing energy consumption of different MAC protocols, energy consumptions of different radio devices are compared, finding which radio device is suitable for DISNs application.

2. Experiment, Results, Discussion, and Significance

In this paper, an experimental TDMA¹² MAC protocol is developed to compare energy consumption of different radio devices. In evaluation, crossbow IRIS mote (RF230) and MICAZ (CC2420) mote are used. IRIS has 250 kbps for data rate. Comparing to the mote MICAZ, IRIS has double program memory (8KB) and also provides three times longer radio ranges.

In order to implement an energy efficient MAC protocol, it is necessary to check energy consumption of each radio state and sampling period of each radio. Oscilloscope device is used to measure such energy consumptions. Table 1 shows the summary of

¹⁰ Sampling interval is the amount of time sensor node waits before collecting each sample.

¹¹ Duty cycle is the proportion of time during which sensor node is active across sampling interval.

¹² TDMA is Time Division Multiple Access. Each sensor has an allocated time to transmit data to avoid collision from data transmission of other sensor nodes.

energy consumption of RF230 and CC2420.

Table: 1
Energy comparison for two radio devices in each state

Radio	RF230		CC2420
	1.6 (dBm)	-0.2 (dBm)	0 (dBm)
Transmit State	18 (mA)	17 (mA)	18.2 (mA)
Receive State	17 (mA)	17 (mA)	20.4 (mA)
Sleep State	6.2 (mA)	6.2 (mA)	6.2 (mA)
Idle State	12.2(mA)	12.2(mA)	12.2 (mA)

Figure 1 is a snapshot of energy consumption of RF230 mote for one sampling period. In order to obtain energy consumption of a sampling period, one sampling period is divided into k sections so that each section can have a linear equation. X-axis presents time (ms) and Y-axis presents a corresponding voltage value of kth section.

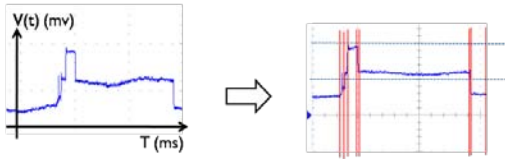


Fig.1. Dividing one sampling period into k sections

Therefore, the total energy consumption (E) of one sampling period from time t to $\Delta t * n$ where n is the number of the divided sections can be calculated with the following formula:

$$E = \sum_{k=0}^n \frac{V_{in}}{R} \left(\int_{\Delta t(k-1)}^{\Delta t k} a_k t + b_k \right) dt \quad (1)$$

In the experiment, the input voltage V_{in} is 3.0 (V) and, the resistance R is 1.0 (Ω), and a and b are constant values. The equation (1) is used to calculate energy consumption of a sampling period with duty cycle 20%, different transmission power levels and different radios as shown in figure 2 that more sampling period contributes on saving energy due to a decrease in the number of transition operation by increasing sampling period. When comparing various transmit power level of RF230 itself, it is obvious that higher transmit power level consumes more energy. Interestingly, when power level of RF230 is 1.6dBm, its energy consumption is close to the energy consumption of CC2420 when its power level is 0dBm. The result clearly says that RF230 consumes less energy with more radio ranges comparing to CC2420.

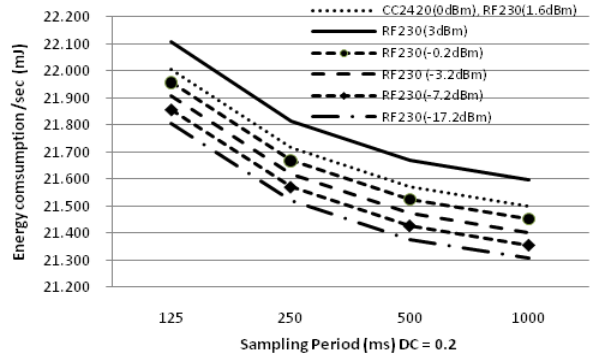


Fig.2. Energy consumption (mJ/sec) for various transmission power levels for MICAZ (CC2420) and IRIS (RF230)

3. Conclusion

As the experiments show that RF230 is more energy efficient and suitable for DISNs than CC2420, selecting a right sensor device with less energy consumption is one of important factors in order to evaluate energy efficient MAC protocols in DISNs, where extremely energy saving condition is required. Current phase of evaluation compares two different devices. The future work includes comparison of other various radio devices, and implementation and evaluation of configurable MAC protocols based on different radio.

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5. References

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