*Proceedings of the Asia-Pacific Advanced Network **2011** v. 32, p. 101-105.*

CAP (Coordinated Adaptive Power) Management Technique with Adaptive Threshold Policy for Wireless Sensor Nodes

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http://dx.doi.org/10.7125/APAN.32.12 ISSN 2227-3026

Abstract: Small size of the sensor nodes put constraint on the hardware capabilities and battery supported on it. Though power optimization is a real challenge in all WSN applications, power saving at the cost of data loss is not at all preferable. Very small buffer sizes cannot store the increased data arrival at the time of event occurrences and data gets lost due to buffer overflow. Data loss within the node occurs before transmission mainly either data gets timed out or due to buffer overflows. Both of these situations can be handled using CAP management techniques at individual sensor nodes. Here Dynamic Voltage Frequency Scaling (DVFS) and Dynamic Modulation Scaling (DMS) techniques are used for optimization of power consumed by processor and transmitter respectively. We have considered that DVFS and DMS are coordinated together so that whenever processor changes its processing speed, transmitter also changes its transmission rate and minimum data loss occurs at the intermediate buffer. In this paper we have discussed adaptive threshold policy for selecting a particular state of sensor node and compared the results with fixed threshold policy. CAP management along with adaptive threshold policy improves the lifetime of sensor nodes and also reduces the data loss before transmission.

Keywords: CAP management, adaptive threshold policy, buffer congestion

1. Introduction

With CAP management we are trying to adaptively change the power consumption of sensor nodes. Service rate of processing unit and communication unit are coordinated together and changed adaptively with respect to the workload. Here we consider a wireless sensor node supported with DVFS [1] and DMS [2] power optimization techniques. Coordinating DVFS and

DMS on a sensor node give rise to Coordinated Adaptive Power (CAP) management [3]. Here by service rate we mean the processing rate (clock frequency-f) of the processor and data transmission rate (number of bits per symbol-b) of the radio transmitter. As few discrete service rates are supported by the servers, it becomes important to select a particular service state by comparing the data in the buffer with the threshold. For convenience we consider a node which has two ON states- ON1 and ON2. In ON1 state service rate is higher and the power consumed is more while in ON 2 state service rate is lower as well as power consumed is less but more service time is required. Switching between the states takes place by comparing the number of packets in the buffer with set threshold. A sensor node capable of providing two service rates results in longer lifetime than that of sensor node with fixed service rate as it works with lower rate and consumes less power when there is small workload to carry and save the power. Higher service rate used only during workload is heavy (catastrophe), it reduces data loss due to buffer congestion. Figure 1 shows the tandem queue equivalent model of sensor node used for analysis and simulation.

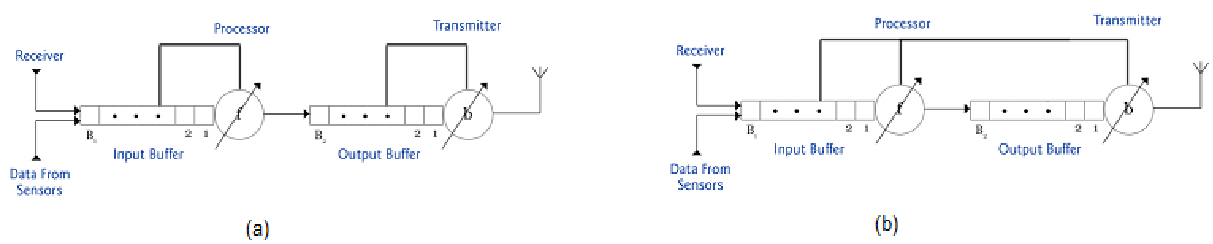

Figure 1: (a) Tandem queue model of sensor node having DVFS and DMS applied independently, (b) DVFS and DMS coordinated together with input buffer occupancy.

2. Previous work

Threshold policies are needed whenever to choose the better one between two or many possibilities. Threshold policies are used for selecting a particular data rate at wireless switch or router in order to increase the throughput [4, 5]. Adaptive threshold policy has been used in [6] but the aim of using adaptive threshold policy is to change the transmission rate with time variable channel conditions. Threshold policies are also used for memory sharing between various sources as per their priority. In this paper we consider buffer threshold policy which enables the sensor node to vary its service rate with respect to buffer occupancy so that data loss due to buffer overflow can be minimized along with power optimization resulting in the increased lifetime of the node.

3. Threshold policies

Single threshold policy: For a finite sized buffer a threshold value is set such that whenever the number of packets in the buffer is more than the threshold K, server switches to the high service rate consuming more power but reduces the possibility of data loss due to buffer overflow. On the other hand if the number of packets in the buffer are less than or equal to the threshold K, server continues in the low power state consuming less power and working with low service rate. It reduces the idle period and power consumption but increases the possibility of data loss due to buffer overflow.

Dual threshold policy: Single threshold policy is suitable when the traffic arrival rate does not change abruptly and very frequently because for such traffic arrivals we may need to switch the service rates in consecutive time slots. Switching the state consume extra time and extra power which may over weigh the power saved by working with lower service rates. It is better to have some margin before switching to another state. It helps in reducing switching energy and switching time overheads. In dual threshold policy two thresholds K1 and K2 have been defined such that K2 > K1. At the start of a new slot if number of packets in the buffer is more than K1 and less than K2 then server will continue with the service rate as in the previous slot. Service rate will change only when buffer occupancy is outside the margin.

Adaptive threshold policy: In this policy also the sensor node changes its service state by comparing the buffer occupancy with the buffer threshold. Difference is that here buffer threshold is not fixed. Threshold level is varied with respect to the buffer overflow in previous slot along with the buffer occupancy. If the buffer overflow is approaching near the tolerable value then the threshold is decreased so that server can enter in high service state and buffer overflow possibility is reduced. On the other hand if the buffer overflow in the previous slot is negligible then the threshold value can be raised so that server remains in low power state and power is saved.

4. Simulation results

We have simulated a tandem queue model of wireless sensor node in MATLAB. M/M/1/N model (N=6) has been considered for processor as well as for transmitter. We consider a periodic time out sleep schedule and assume that during the ON period channel condition doesn’t change significantly. Table 1 indicates the various observations by simulation.

Table 1. Effect of fixed and adaptive threshold on lifetime of sensor node
(Suffix 1 refers to input buffer and suffix 2 refers to output buffer)

Threshold (K1,K2)	Average idle period		Normal overflow probability		Catastrophic overflow probability		Lifetime (time units)
	I1	I2	Ov1	Ov2	Ov1	Ov2	
Fixed (3,3)	0.3906	0.4351	0.0186	0.0261	0.3048	0.3245	24660
Adaptive (3,3)	0.3344	0.3470	0.0382	0.0257	0.2852	0.1989	58361
Fixed (4,4)	0.3919	0.4041	0.0167	0.0159	0.4170	0.3133	34163
Adaptive (4,4)	0.3350	0.3709	0.0276	0.0162	0.3043	0.1813	63481

Fixed (3,3) indicates the threshold values for input and output buffer are 3 and 3 and remains fixed. Adaptive (3,3) indicates the starting threshold values are 3 and 3 but adaptively changes with buffer overflow and buffer occupancy at the start of each time slot.

5. Conclusion

Simulation results show that the lifetime of a sensor node capable of working with two service rates can be increased by using adaptive threshold policy as that with fixed threshold policy. It also reduces idle time period and power loss during idle period. Overflow probability during catastrophic periods can be reduced further by selecting little higher service rates along with adaptive threshold. If number of service rates offered by a node are more than two then instead of using single adaptive threshold policy, multiple fixed thresholds are needed to select required service rate. A sensor node with multiple service rates is much complex than that with two service rates and also switching power and switching time overheads increases. So it is a better option to achieve the long lived wireless sensor networks having sensor nodes offering two service rates with adaptive threshold policy. Adaptive threshold policy also helps to reduce the number of switching between the states.

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