A Context-Aware Wireless Sensor Networks for Efficient Low-Power Management

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Abstract—We present a context-aware wireless sensor network (WSN) for efficient low-power management. We apply a context-aware scheme to the sensor nodes and the gateway to reduce WSN power consumption.

I. INTRODUCTION

A major issue in wireless sensor network (WSN) devices is poor power consumption [1]. Because most wireless sensors are battery or solar powered, reducing the power consumption of the wireless sensors can increase the battery lifetime or decrease the capacity needed by the energy harvester.

In this paper, we present a context-aware WSN in which context information is used to save energy. Our research of low-power technologies will focus on an intelligent cross-layer approach between the network and the application layer. The state of being context aware provides WSN devices with intelligence needed to make appropriate decisions. The rules are installed and evaluated at the sensors to reduce the application traffic and the wake-up/sleep intervals of the network routing.

II. CONTEXT-AWARE SCHEME FOR POWER EFFICIENCY

The proposed context-aware WSN in a typical mesh topology are shown in Fig. 1. Contextual information enhances the intelligence of an application's behavior using these recognized contexts [2]. Fig. 2 shows the message flow of a context-aware WSN. First, the gateway registers the sensor and allocates the short address. Second, the WSN devices require time synchronization of synchronized low-power routing (LPR) [3]. The recognized contexts may exchange a specific rule. The gateway executes the desired action by transferring the appropriate rules to the sensor. The basic rules, which are transformed into general format by the gateway, specify various sensing conditions under which to reduce unnecessary sensing information as much as possible. When the request that includes the rule is passed from the gateway to the sensor, its own ID is assigned to the command. As a result of the command, the sensing value including the ID is passed to the gateway. The ID is used to identify the command in the gateway. Additionally, when the command ID is unchanged but the command parameters change, a command renewal is called.

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Fig. 1 Mesh topology of a context-aware wireless sensor network

Fig. 2 Context-aware wireless sensor network message flow

TABLE I
RULES SET FOR THE CONTEXT-AWARENESS AT THE SENSORS

Rule	Description (Value)
Sensing Mode	One-time or periodic sensing mode Passive (0), Active (1)
Wake-up Interval	Sniff period for LPR (0~FFFFFFFF)
Threshold	Threshold value (0~FFFFFFFF)
Threshold Operator	Operator between sensing value (S) and threshold value (T)
Sensing Type	Select sensing type to collect
Fusion Operator	Operator for data fusion within specified duration
Fusion Duration	Specify a multiple of wake-up interval

As shown in Table 1, we defined a set of rules related to the sensing mode, the wake-up interval, the threshold, the sensing type, and the data fusion. The gateway specifies when an active or passive sensing mode is required by the sensor. In the passive sensing mode, the sensor performs a one-time sensing operation for the request. The active sensing mode involves lifetime and interval information upon gateway request, so the sensor actively senses during a set period of time. The wake-up interval specifies the sniff period of the synchronized LPR (SLPR). When the WSN application needs

to reduce power consumption, the gateway increases the wake-up interval of the sensor. The sensed data filtering can be employed using a specified threshold, its operator, and its sensor type. This can reduce the amount of data that must be sent to the gateway. This prevents transmission power waste, the major source of power consumption in the sensor. The fusion operator and the duration comprise part of the sensor cache memory that is used for the sensed data. They determine the specified period and calculate the fusion value by the operator, which can also reduce the number of transmissions of the sensed data.

Fig. 3 Architecture (a) and the function flow of the context-aware shim in the sensor node (b)

Fig. 4 Transmitter (TX) algorithm of the network layer in the sensor node

Figure 3(a) shows the architecture of the sensor. It includes the context-aware shim that means light-weight middleware. The context-aware shim consists of the rule repository, the rule executer, and the context and node managers. Figure 3(b) shows the function flow of the context-aware shim. Figure 4 shows the TX algorithm of the network layer in the sensor. Because a rule relies on the situation, the gateway dynamically sends or changes the suitable rule to the sensor. The traditional SLPR uses the fixed wake-up interval predetermined by the network coordinator. We propose that the wake-up interval can be changed when the power saving is more important than the delay caused by increasing the wake-up interval. The sensor checks the rule and sends the sensing data while repeating the wake-up/sleep cycle.

Context awareness, in terms of the power-saving aspect, needs to be able to determine the desired action according to the situation and the past experience of the application to reduce the redundant actions. It is necessary that only the desired and important information is delivered to the gateway. We describe some practical scenarios for applying the specified context to save power.

The threshold value can be configured according to an application's interest. For example, only when the current temperature is larger than the threshold the sensor send the current temperature to the gateway. Similarly, the sensing

mode and the sensing type rules can be activated. The rule defines several threshold operators for comparison and arithmetic between the sensing value and the threshold value. If the gateway sets the threshold value to the latest sensing data and sets the threshold operator to not equal, the sensor only sends the sensing data. The recognition of valuable data and the analysis of the patterns of incoming data are performed in these scenarios. In another scenario, the gateway will apply a proper fusion operator and sensor duration when the gateway is interested in the average temperature over a period of time.

There is also an application that checks the freezing status of the road to sense temperature and humidity. If sub-zero temperatures and high humidity are sensed, the road is likely to be frozen. However, if the temperature is above zero, the road has almost no chance of freezing regardless of humidity. In this case, the gateway would stop or slow the humidity data collection because it is not important. Therefore, if the gateway applies suitable application-dependent rules, the sensor can reduce unnecessary power consumption.

TABLE II

TRAFFIC REDUCTION RATIOS BY SENSOR TYPE			
Sensor Type (Number)	Node Description	# of traffic/h (Reduction Ratio)	Applied Rules
T	One temperature sensor	2,694 (25%)	Single rule (temperature)
T+H	Each node has one sensor	4,927 (32%)	Two rule (humidity, temperature)
TI	One node has two sensors	2,137 (41%)	Two rule (humidity, illumination)
TI(2)+H(2)	Complex four nodes	12,578 (17%)	Single rule (humidity)
TI(2)+H(2)	Complex four nodes	9,844 (32%)	Two rule (humidity, temperature)

Table 2 shows the traffic reduction ratios by sensor type. Each sensor senses temperature (T), humidity (H), and illumination (I). Each node senses once a second or 3,600 times per hour. We assume that each rule for each sensor is applied with 50% probability. The applied rule increases the frequency of the data transmission by approximately twice. The traffic reduction ratios of combinations of different sensor readings on the same node are relatively high since the same rules are applied.

III. CONCLUSION

A new context-awareness scheme functions by determining the rules in such a way that lower power amounts are consumed as a result of the context awareness of the ongoing situation. The proposed context-awareness scheme significantly decreases power consumption by optimizing the network traffic as much as possible.

REFERENCES

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