A Delta-based Data Aggregation Scheme using EWMA in Wireless Sensor Network

Byun-Gon KIM¹, Kwan-Woong KIM², Jung-Won CHOI³ and, Yong-Kab KIM³,

¹ Department of Electronic Engineering, Kunsan National University, Kunsan, Korea
² Thunder Technology, Director in Digital Signal Processing Team, ChonJu, Korea
³ Department of Information and Communication Engineering, Wonkwang University, Iksan, Korea
{bgkim@kunsan.ac.kr, kwkim@thunderspeaker.com, ykim@wonkwang.ac.kr}

Abstract. In a wireless sensor network, a middleware used to support efficient processing and fast delivering of sensing data should handle the data loss problem at an intermediate sensor node caused by unexpected sudden data burst. In this paper, we proposed data aggregation method based on EWMA for enhancing the efficiency of data aggregation and accuracy where the sensed data should be delivered only with the limited computing power and energy resource. With the proposed method, unnecessary data transfer of the duplicate data is eliminated and data correctness is enhanced by using the proposed averaging and data differentiating scheme when an instantaneous data burst is occurred. Finally, with the TOSSTM simulation results on TinyDB, we verify that the correctness of the transferred data is enhanced.

Keywords: Wireless Sensor Networks, Middle Ware, Data Aggregation, Overflow.

1 Introduction

In recent years, with the development of sensor technology and wireless communication technology, data processing-oriented middleware for wireless sensor network applications are being actively developed. Wireless sensor network consists of numerous sensors, each sensor node should handle tasks such as sensing, query writing, query dissemination, collection, processing, transmission[1].

In particular, there is high data redundancy in the wireless sensor network which has high node density.

Data merging technique is used to reduce these excessive redundancy and data transfer. Merge techniques used in wireless sensor networks aggregate, depending on how the techniques and all the data merge operation is performed on the host root.

Data merging technique would be classified to the server-based approach and in-network aggregation [2]. The server-based approach is based on the routing tree from the top-level root node to the leaf nodes, merging operation is performed in the root node and all leaf nodes transmit all received data including its sensing data to the root nodes.
node. While intermediate nodes perform merging operation of all receiving data in “in-network aggregation”.

Because the final destination; the root node perform the merge operation in the server-based techniques, all data should be sent to the root. This technique requires the transmission of data messages from all the nodes; therefore the traffic shall be increased.

Merge process of in-network aggregation is shown in figure 1, Where f(x) is the aggregation function.

Intermediate nodes located in the routing path merge two values (one is sensing value X by itself, another is Yk received from child nodes) into a single message by using aggregation function f (X, Yk), then it is passed on to their parent node.

In this way, each node sends a message by using the aggregation function; this technique can minimize the number of messages transmitted.

However, the accuracy and rapidity of data transfer is degraded in this technique. To overcome these shortcomings, an efficient data merging techniques are required.

In this paper, we proposed the in-network data merge technique based on Exponential Weighted Moving Average (EWMA). The proposed data merge technique improves accuracy and efficiency to merge data from a wireless sensor network environment, while providing rapid data transfer.

2 EWMA data aggregation technique

An exponential weighted moving average (EWMA), also known as an exponentially weighted moving average (EWA)[3] is a type of infinite impulse response filter that applies weighting factors which decrease exponentially. The weighting for each older datum point decreases exponentially, never reaching zero. The graph at right shows an example of the weight decrease.

In this paper, the proposed scheme, when sensor node should transmit measured value to the root node, each sensor node performs data merge process as follows.

Step 1) Node calculate weighted average of all received measured value including measured value by itself using EWMA.

\[
\bar{x} = \alpha \cdot \bar{x} + (1 - \alpha) \cdot x
\]  

(1)
A Delta-based Data Aggregation Scheme using EWMA in Wireless Sensor Network

Where \( \bar{x} \) is average value, \( x \) is a new sensing value. The coefficient \( \alpha \) represents the degree of weighting decrease, a constant smoothing factor between 0 and 1. A higher \( \alpha \) discounts older observations faster and \( X_{TR} \) is a message to be sent.

Step 2) After a certain time elapsed, a node set \( \bar{x} \) to \( X_{TR} \) and transmit \( X_{TR} \) for the first transmission.

Step 3) From second transmission, a node calculates \( \bar{x} \) for all received sensing data. If \( |X_{TR} - \bar{x}| > T_h \) or \( |X_{TR} - x| > T_h \) then a node transmits \( X_{TR} = \bar{x} \), else a node transmits \( X_{TR} = x \).

Step 4) Iterate step 3.

Main idea of the proposed algorithm is that adaptively adjust the degree of heterogeneity between the data values to minimize the loss of value due to averaging methods. Therefore proposed approach was to improve the accuracy of the final results are passed to the root node data.

Decision of threshold \( T_h \) depends on quality value in inquires and network condition.

3 Performance Evaluation

TOSSIM simulator of Tiny OS[4] is used for access performance of proposed data aggregation scheme. Middleware for data aggregation is TinyDB[6] and EWMA is used for average measurement.

TOSSIM simulator supports mic 40Kbit RFM-based stack and TinyOS CSMA protocol. Topology is multi-hop routing based on tree structure using SRT of TinyDB.

Sensor network consists of 5 nodes. Each node has illumination sensor to measure illuminance.

The proposed EWMA aggregation scheme is compared with delta aggregation technique that provided by TinyDB in terms of fidelity and latency for access performance.

Fidelity measures accuracy of data that is transmitted to root node.

As shown in figure 2, measured value by EWMA method is closer to original illuminance value than delta method. Main reason is that a node transmits average value instead of transmitting measured value when drastic illuminance change is detected.

Figure 3 depicts average end-to-end latency according to queue size. In delta method, node aggregate all measured value when buffer overflow is occurred. As shown in figure 3, the proposed scheme show better performance than delta method.
Fig. 2. (a) Original illuminance value (top), measured by delta method (middle), measured value using EWMA method (bottom). (b) End to end latency vs. queue size.

3 Conclusion

We proposed data aggregation scheme based on EWMA to solve problem such as overflow occurrence in intermediate node due to instant burst traffic and improve efficiency of data management in wireless sensor network.

To achieve performance improvement, the proposed algorithm uses variation of measured values and exponential weighted average method to improve accuracy of sensing data and avoid network congestion.

From simulation result, the proposed data aggregation scheme improves performance in terms of network efficiency and latency compared to conventional data aggregation scheme.

References