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Data Compression Schemes for WSN Nodes Used for Data Acquisition of Slowly Changing Digital Events

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***Abstract*— In this paper, minimization of energy required for transmission by nodes in a class of WSNs deployed to sense digital events is considered. Energy conservation directly leads to increased lifetime of a WSN. Considerable reduction of transmission energy can be achieved by reducing the number of bits transmitted to convey the same digital signal values. In an earlier paper, we considered some schemes for minimizing the number of transmitted bits. We have extended that work further as reported in this paper. The new scheme proposed in this paper involves grouping of 1 and 0 time periods in a matrix format and transmitting the matrix dimensions. We show that for digital signals with very long runs of 1s or 0s considerable reduction of transmitted energy can be achieved**

***Keywords*—WSN, Energy Minimization, Sensor Node, Digital Signal**

I. INTRODUCTION

A desirable requirement for Wireless Sensor Networks (WSNs) is conservation of energy and consequently prolonging the lifetime of the network. Often WSNs are deployed on a one-time use basis for acquisition of data from unknown environments. Fig. 1 shows the major components of a typical wireless sensor node employed for sensing digital events. As shown by Pawar et. al. in [1], through empirical energy consumption modeling of a WSN node, the radio module consumes the maximum amount of energy while transmitting data to other nodes. Therefore, it is desirable to minimize transmission time of the radio module as much as possible. The energy consumption by the radio during transmission is given by the following equation [1]:

$$E = T(n) * I_t * V_s \tag{1}$$

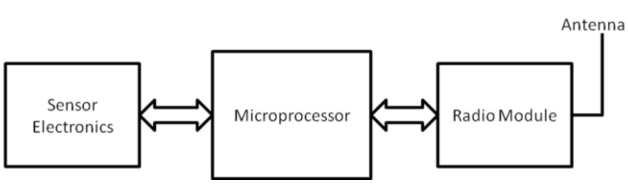

Fig 1: Schematic diagram of a typical WSN sensor node

Where,

$T(n)$: Transmission duration for 'n' bits,

I_t : Current drawn by the radio , and

V_s: Nominal battery voltage.

As per the IEEE 502.15.4 which has 31bytes of overhead for each transmission, T(n) is given by the following equation:

$$T(n) = 8*(31+B)/R_b \tag{2}$$

Where,
B: the number of bytes of data to be transmitted, and
R_b : bit rate in bits per second.

Therefore, by minimizing the number of bits of transmission, we can reduce the energy consumption by a WSN node. The information that is relevant to the specific application scenarios should be compressed into as few bits as possible [2]. We have shown in [2] that for a special class of WSNs employed for data acquisition of sampled analog data from slowly varying parameters, it is possible to reduce the number of bits per sample from the full length to achieve energy minimization. We further extended the work in [2] to the case of WSNs required to monitor digital events and convey the information to the sink node [3]. In this paper we propose another method involving grouping of transmission periods and sending the grouping information to the sink node. In the following sections, details of the proposed scheme for digital data compression and results of simulation are presented.

II. RELATED BACKGROUND

With a view to explore newer methods to minimize energy consumption by nodes in WSNs, in an earlier paper [2], energy minimization approaches suitable for a specific class of applications involving very slowly varying anolog signals were presented. This work was further extended in [3] for the case of data acquisition applications involving digital signals. To the best knowledge of the authors, this is a new line of research.

A very exhaustive and useful survey of energy conservation methods applicable in WSNs in general can be found in [4]. The focus area of our paper relates to data compression which can be done in several ways (e.g., [5]-[7]). However, many of the general purpose data compression methods are difficult to be adopted for implementation in WSN consisting of large number of low cost nodes that are usually very much limited in processing and memory resources. The proposed new data compression scheme of this paper as also those of [2] and [3] are most applicable in such WSN implementations.

III. Proposed Scheme

In the proposed scheme for data compression, instead of sending time stamp for every 1-0 or 0-1 data transition, the periods of 1s or 0s are encoded by assembling all the 1 and 0 periods separately in a matrix format. This results in less number of bits to be transmitted as compared to transmitting time stamps alone. In the following, the time-stamps-only scheme called here as the Straight Forward Scheme (SFS) is presented first followed by a brief indication of the schemes presented by us earlier, and then the new matrix based scheme proposed in this paper.

A. Straight-Forward Scheme (SFS):

Fig. 2 shows a portion of a digital signal with T1 and T2 as the periods of 1 and 0, respectively. These time periods can be expressed as integral multiples of the sampling period t_S. A sensor node can transmit to the sink the time stamps (24 bits to represent day, hour, minute, and second) and whether the transition is a 0-to-1 or a 1-to-0, which requires an additional bit. Using this information, the digital signal can be reconstructed by the sink.

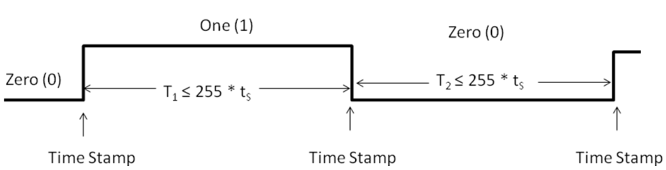

Fig. 2 A portion of digital input signal

We consider here, for simplicity and as an example, only a digital event consisting of 128 periods with alternating 1s and 0s. As there are 129 transitions and 25 bits are required per transition, the number of bits required to be transmitted by a sensor node is 3225. We can minimize the number bits to be transmitted and consequently the energy consumed for transmission by compressing the bit data by adopting schemes that codify time period T_i of continuous 1s or 0s.

Three compression schemes [3] proposed by the authors are briefly presented below as a prelude to the new matrix based scheme of this paper.

B. Earlier Proposed Schemes:

In the first scheme presented in [3], the durations of 1s and 0s are considered separately, and expressed in terms of the sampling duration t_S. The number of bits required to transmit a sequence of 1s and 0s is

$$N_b=24+\sum\{FLOOR(L_i/(2m-1)+1\}*(m+2) \qquad (1)$$

where,

L_i = length of the ith duration (1 or 0) and i= 1 to 128.
m= number of bits for time period representation.

In the second scheme of [3], m is made variable to further minimize the number of transmission bits. The total number of bits required as per this scheme can be expressed as

$$N_b=24+\sum(7+k_i) \qquad (2)$$

where,

k_i = number of bits required to represent 1 or 0 period.

In the third scheme of [3], a period of 1s and followed by 0s together are considered as one cycle of a square wave, and is specified by the half period and an indication whether it starts with a 1 or 0. In this case, the number of bits required for transmission is given by

$$N_b = 24 + \sum(3+m) + (4+k_i) \qquad (3)$$

where,

m= number of bits required for half period representation, and,

k_i = number of bits required to represent the period equal to the difference between T_1 and T_2 (shown in Fig 2).

C. Proposed New Scheme:

The method of compression as per the new scheme can be explained considering the example digital signal shown in Fig. 3. As seen in this signal, the '0' periods are $T_{1,0}$, $T_{3,0}$,$T_{5,0}$,...$T_{n-1,0}$ and the '1' periods are $T_{2,1}$, $T_{4,1}$,$T_{6,1}$,...$T_{n,1}$ in a block of 'n' 1-0 time periods (n: even). If we collect all the '0' periods and represent each by a horizontal bar, and put them one below the other, we get the representation shown in Fig. 4. We can represent similarly the '1' periods.

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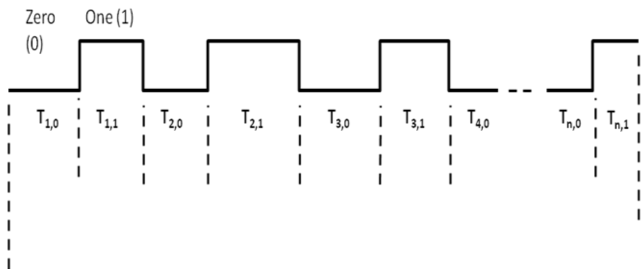

Fig. 3 A portion of digital input signal

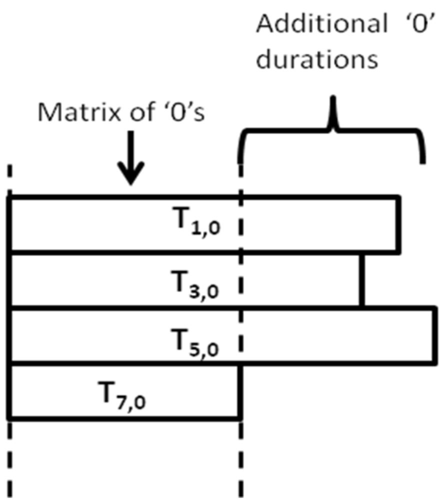

Fig.4 Grouping of '0' periods

As seen in Fig.4, when the '0' periods are stacked together, we can identify a matrix with n/2 rows and column width equal to the shortest among the intervals $T_{i,0}$. As 'n' is fixed and known by the sink, we need not transmit value of 'n'. Also, as the order of the '0' and '1' periods in the stacked representation is known, the sink can reconstruct the original digital signal by knowing the column width of the matrix and additional '0' (or '1') durations associated with each row of the matrix as shown in Fig. 4. The additional '0' durations can be much smaller than $T_{i,0}$ if the difference between Max{ $T_{i,0}$} and Min{ $T_{i,0}$} is small. Therefore, the additional '0' durations can be represented and sent by a node using less number of bits than required for representing the entire $T_{i,0}$ period. This leads to a minimization of number of bits to be transmitted and consequently leads to reduction of energy consumed for transmission by a node. The number of bits that need to be transmitted for conveying values of '0' periods is given as

$$N_{b0} = 24 + \text{Bits}(\text{Min}\{ T_{i,0}\}) + \sum \text{Bits}(T_{i,0} - \text{Min}\{ T_{i,0}\}) \quad (4)$$

where,

Bits(X)= number of bits required representation of X.

Similarly, number of bits that need to be transmitted for conveying values of '1' periods is given as

$$N_{b1} = 24 + \text{Bits}(\text{Min}\{ T_{i,1}\}) + \sum \text{Bits}(T_{i,1} - \text{Min}\{ T_{i,1}\}) \quad (5)$$

and the total number of bits required to transmit the block of data under consideration is

$$N_b = N_{b0} + N_{b1} \quad (6)$$

IV. Simulation And Results

The proposed new scheme was simulated for a single node by generating random samples of data. For simplicity and as typical input, a digital signal with 128 periods of alternating 1s and 0s is considered. In the simulation, random numbers generated represent the 1 and 0 periods. The maximum value of 1 or 0 periods is set as $255t_S$. Figs 5 and 6 show the simulation result comparing the new matrix based scheme with the SFS and scheme 1 of [3] with 5,6,7 and 8 bits. As seen from the results, the matrix based scheme is better than all the other schemes except for the scheme 1 with 8 bits.

V. Conclusion

In this paper, we have extended the work in [3] by presenting yet another new scheme for compressing data pertaining to slowly changing digital signals. The new scheme presented in this paper results in considerable reduction in energy required to convey information about slowly varying digital signals to the sink node. The reduction in number of bits to be transmitted is achieved by grouping 1 and 0 periods to form a matrix data structure with fixed number of rows, and conveying only the column width and the any additional bits outside the matrix. Therefore, this scheme achieves higher energy minimization when the different periods of 1s and 0s do not vary very much and are close to each other. This scheme can be used in addition to those presented in [3] to adaptively minimize the number of bits to be transmitted depending on the observed variation of the input signal. These new schemes along with the methods presented in [2] for analog signal data can considerably improve the life time of a WSN.

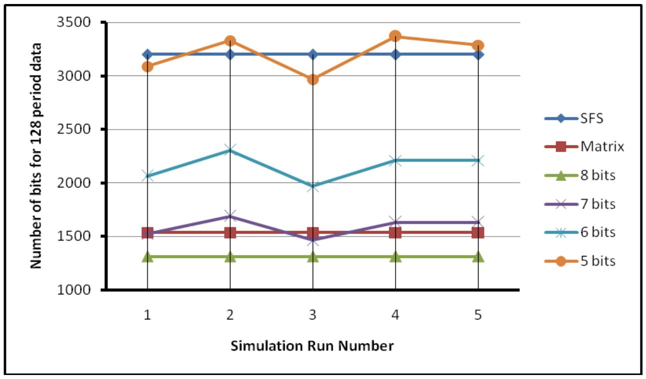

Fig. 5 Number of bits to be transmitted for 128 period data

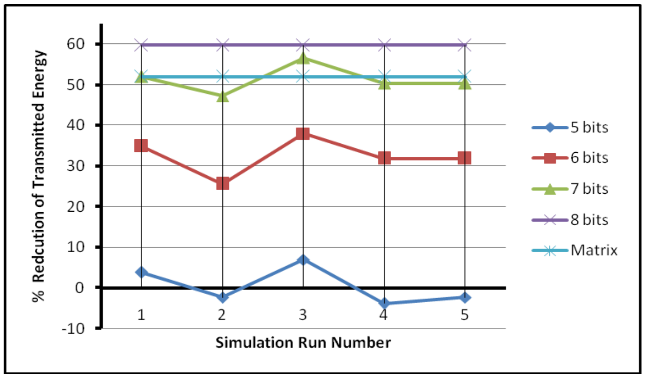

Fig. 6 Percentage reduction of energy required for transmission

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