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Energy Efficient Distributed Decision Fusion for Wireless Sensor Network

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Abstract: A wireless sensor networks (WSNs) is a set of hundreds of micro sensor nodes capable of sensing and establishing wireless communication. A typical wireless sensor network consists of a fusion center and number of sensors. Each sensor is characterized by low power constraint and limited computation. Battery power is the main consideration in the wireless sensor network and hence a new sensor censoring scheme is proposed to further exploit its energy efficiency capability. It allows each sensor to transmit binary decision either 1 or -1 to the Fusion center only when the reliability of its observations on the environment is beyond a given threshold level. The main issue of this work is to minimize the fusion errors and obtaining the optimum energy saving rate. Our goal is to minimize the error performance of the proposed censoring mechanism by using the Distributed Decision fusion. Bandwidth efficiency for wireless sensor networks is improved with low power consumption.

Key words: Optimum energy saving rate · Its observations on the · Networks is improved

INTRODUCTION

A wireless sensor device is a battery-operated device, capable of sensing physical quantities. In addition to sensing, it is capable of wireless communication, data storage and a limited amount of computation and signal processing[1]. Advances in integrated circuit design are continually shrinking the size, weight and cost of sensor devices, while simultaneously improving their resolution and accuracy. At the same time, modern wireless networking technologies enable the coordination and networking of a large number of such devices[2]. A wireless sensor network (WSN) consists of a large number of wireless-capable sensor devices working collaboratively to achieve a common objective. A WSN has one or more sinks (or base-stations) which collect data from all sensor devices. These sinks are the interface through which the WSN interacts with the outside world. The basic premise of a WSN is to perform networked sensing using a large number of relatively unsophisticated sensors, instead of the conventional approach of deploying a few expensive and sophisticated sensing modules. The potential advantage of networked sensing over the conventional approach can be summarized as greater coverage, accuracy and reliability at a possibly lower cost. The range of potential applications that WSNs are envisaged to support, is tremendous, encompassing military, civilian, environmental and commercial areas. Some examples include networked sensors for military surveillance, smart sensors to monitor and control manufacturing facilities, biosensors for health applications, sensor networks to monitor habitat or weather and smart sensor environments for home electronics[3]. Designing, manufacturing and networking wireless sensor devices to support such a wide variety of applications are a complex and challenging endeavor. As a result, there has been a lot of research activity in the area of WSNs over the past five years or so. Research in the area of

WSNs have been active at several levels, starting from the component level, the system level and all the way up to the application level. The component level research focuses on improving the sensing, communication and computation capabilities of an individual sensor device.

System Model: Figure 1 depicts the typical structure of parallel fusion networks. As illustrated in the figure, there is N sensor nodes observing sensor measurements generated from a common phenomenon according to either H0 or H1, the two hypotheses under test. The prior probabilities of H0 and H1 are assumed to be known and are equally likely. The observation value made by the

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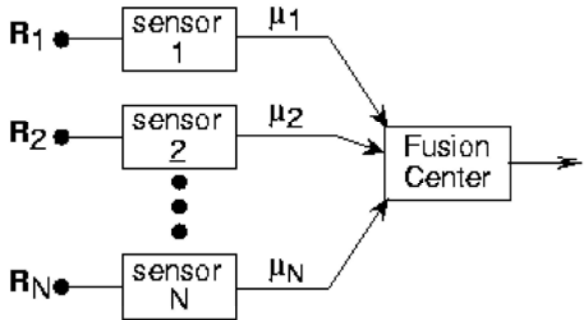

Fig. 1: Distributed Wsn System

N-th sensor is denoted by Z_k and the observations Z_k's, k = 1,...,m, are conditionally independent and identically distributed (i.i.d.) across sensors given each hypothesis. Sensor node makes wireless transmission to fusion center[4].

A) Fusion: Fusion is a collection of packets from different sources. It receives information from many sensors.[5-6] After receiving from all sensor nodes finally they produce quantized and unbiased output[7].

B) Decision Fusion: Decision fusion allows each sensor to send quantized data (decision) to a fusion center[8]. The main advantages of this technique are

- Prevents overloading
- Conserve energy.

In decision fusion, Sensor makes two decisions they are

1)Local Decision: This decision made by sensor node and decision errors will occur

2)Global Decision: This decision is made by fusion center

C) Fusion center: The information sensed by each sensor will be sent to the fusion center and the fusion center makes the global decision[9].
Global decision is carried out by two methods

1) Hard Decision: Demodulator makes the decision on transmission of packets only.

2) Soft Decision: Demodulator provides some information in addition to the packets transmitted. The additional information is used to measure the reliability of the decision

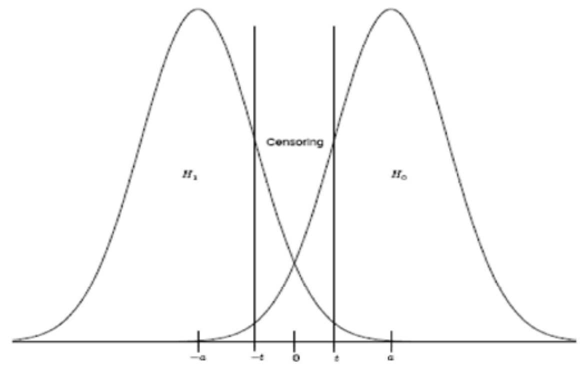

Fig. 2: Decision regions of H_0 and H_1

D)Censoring: Censoring is a technique in which only reliable information is send to fusion center. It will reduce communication burden during wireless transmission to fusion center [10] [11]. Hence power consumption is achieved by censoring the transmission of unreliable packets as in conventional method [12].

Figure 2 plots the conditional distribution given H0 or H1 considered in this work. Notably, the considered observation model is commonly used in the area of distributed detection. However, it may not be suitable for the applications in correlated sensor observations or the event monitoring in which event detection depends on sensor locations[13].

In the considered parallel fusion networks, the k-th sensor makes its binary decision, i.e., U_k, based on its own observation Z_k independent of all other nodes. In addition, this work assumes that an identical local decision rule is employed at each node to facilitate the application for large-scale sensor networks [11]. In the conventional WSN system, the decision rule U_k is applied. An erroneous decision occurs with probability $P[Z_k < 0|H0] = P[Z_k > 0|H1] = Q(a)$, where Q(a) is the standard normal complementary cumulative distribution function (CDF) with the definition Q(a). The signal s_k transmitted to the FC by the k-th sensor is assumed a simple BPSK modulation, i.e., where E is the energy of the BPSK modulation. Hence, the received signal at the FC is $r_k = s_k + n_k$, where n_k is the Gaussian noise in the AWGN channel. All n_k's are assumed i.i.d. and $E[n_k] = 0$, $Var[n_k] = N0/2$ for k = 1, 2,...,m. Both soft-decision and hard-decision decoding rules can be applied on the final decision ˆU at the FC. The hard-decision decoding rule is a majority decision rule, soft decision is an EGC rule. But in proposed method censoring is made and wireless transmission is made to fusion center. Finally soft decision and hard decision is made similarly as in conventional method[9]. Results of both the methods are compared which proves that power is consumed in proposed method.

Simulation: In Conventional method, Hard decision uses majority decision rule and Soft decision uses equal gain combining rule(EGC).The parameters used for simulation are $E_b/N_{0,}$ no of sensors (m) and strength of the signal (a). Energy saving gain is obtained by the following steps

1) Calculation of $q_{e.}$
2) Calculation of p_e
3) Determining Energy saving gain..

where q_e is the error probability of the censored region and p_e is the overall error probability.[14] Average energy consumption is also calculated. Finally the graph is plotted between energy saving gain and the strength of the signal [15].

In Proposed method, Hard decision uses maximum likelihood on majority decision rule and Soft decision uses maximum a posteriori probability rule(MAP). [16]The parameters used for simulation are $E_b/N_{0,}$ no of sensors (m) and strength of the signal (a).But the average energy consumption is varied according to the energy. Energy saving gain is obtained by this methods provide better result compared to the conventional method [17]. Energy conservation is achieved.

RESULTS

The energy saving gain (G_E) is calculated by determining the probability of error which occurs during the observations made by sensor and transmission to fusion center. Graph is plotted with the different values of strength of phenomenon (A) and their corresponding energy saving gain (G_E) by using soft decision and also keeping E_b/N_0 as constant is shown in Fig. 3. The signal to noise ratio (E_b/N_0) is varied and the graph is drawn. As the range of the strength of the phenomenon is increased energy saving rate is reduced. Graph in Fig 3 clearly shows that the Energy saving rate (G_E) can be achieved only when the value of the strength of the observation (A) is low. When "a" value is high, error probability P_e decreases. When "a" value is low, unreliable information is sent to the fusion center and error probability P_e increases. By censoring that unreliable information the probability of error can be decreased.

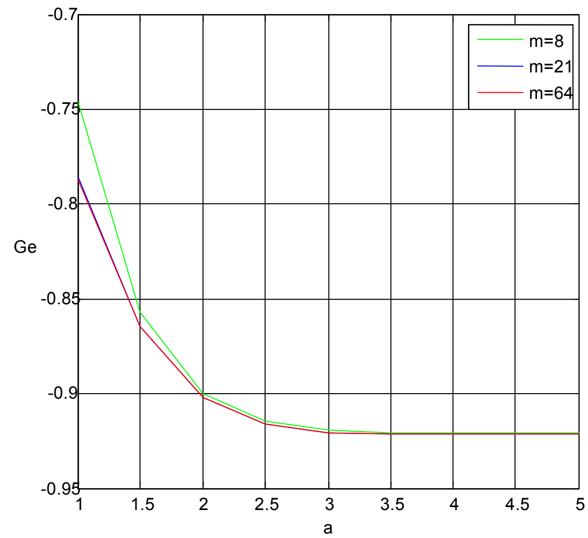

Fig. 3: Soft decision

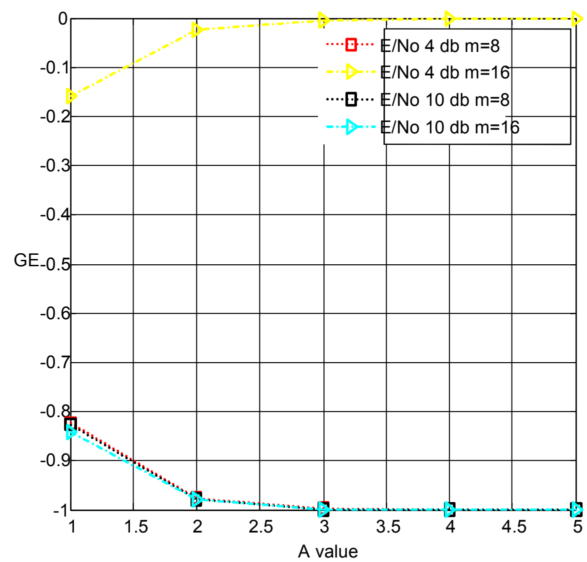

Fig. 4: Hard decision

Similarly for Hard decision graph is drawn between Energy saving gain and Strength of the phenomenon. The energy saving gain (G_E) is calculated by determining the probability of error which occurs during the observations made by sensor and transmission to fusion center. Graph is plotted with the different values of strength of phenomenon (A) and their corresponding energy saving gain (G_E) by using hard decision and also keeping E_b/N_0 as constant is shown in Fig 4. The signal to noise ratio (E_b/N_0) is varied and the graph is drawn. As the range of the strength of the phenomenon is increased energy saving rate is reduced. Graph in Fig 4 clearly shows that the Energy saving rate (G_E) can be achieved only when

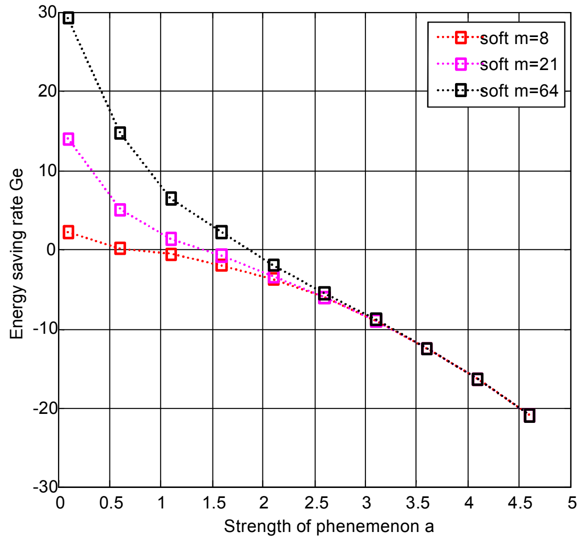

Fig. 5: Soft decision after censoring

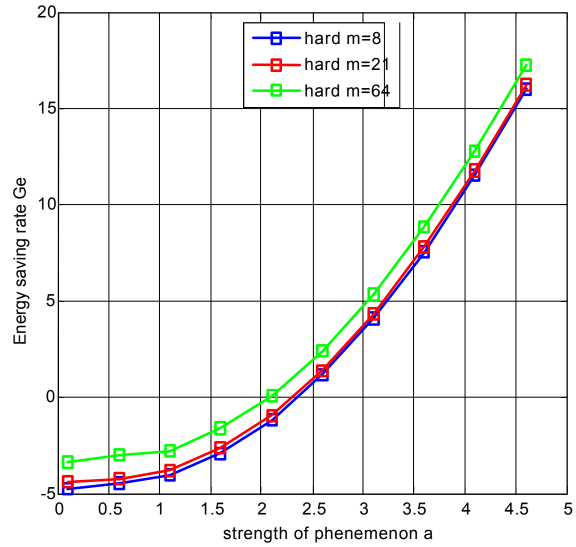

Fig. 6: Hard decision after censoring

the value of the strength of the observation (A) is low but when the no of sensors (m) is high, Energy saving rate increases with strength of the sensor. When “a” value is high, error probability P_e decreases. When “a” value is low, unreliable information is sent to the fusion center and error probability P_e increases. By censoring that unreliable information the probability of error can be decreased. When more sensors are used, the graph provides better result. When strength of the phenomenon (A) increases, Energy saving gain also increases. Hard decision provides better result for more no of sensors as it uses majority decision rule. Soft decision holds good for low no of sensors but hard decision provides better performance when no of sensors used is high. After Censoring mechanism the performance of them is increased.

In Proposed method, Censoring mechanism is done and then soft and hard decision is made at fusion center. Due to Censoring mechanism the performance of the fusion is better than the conventional method. The Energy saving gain GE = (Energy (in dB) needed to achieve the same Pe in the conventional WSN system) - E_1 (in dB), where E_1 = (1 - qc)E = the average energy under the censoring scheme. In figure5 and figure 7 we can infer that for the soft-decision decoding, the energy saving gain is more significant for high SNR (E/N0 = 4dB) than for low SNR (E/N0 = 1dB), especially when a is small. Furthermore, when E/N0 = 10dB and a is not large enough, the error probability of the conventional WSN system cannot be as low as P e even when the energy of the transmitted signal is 8. That is, G_E is infinite unless a is

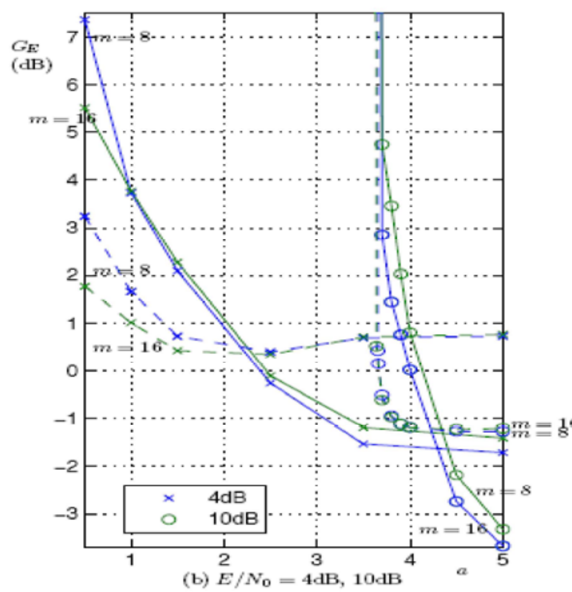

Fig. 7: Soft and hard decision for high SNR

extremely large. This is because the damage caused by a mistake at the sensor cannot be alleviated in the conventional WSN system especially when SNR is high.. Figure 5 shows that energy saving is almost always achieved for the hard decision decoding.

Hard decision holds good for low SNR and at the same time Soft decision is good at high SNR. The Proposed method shows that energy saving is achieved after censoring the unreliable information transferred to the fusion center. The error performance of the proposed censoring mechanism has been analyzed. Thereafter, this work has obtained the corresponding optimum censoring rate to minimize the decision errors at the Fusion center. Power consumption of the sensor node is reduced and the Energy saving gain is achieved.

CONCLUSION

A new censoring scheme to achieve energy-efficient decentralized detection has been proposed and examined under various environments in WSN systems. The proposed censoring scheme differs from the scheme presented in [14] in that only a single-bit instead of the entire LLR value is transmitted to the FC if the LLR falls within the "send" region. [18-20].

The proposed scheme also differs from the scheme in in that the LLR within the "send" region is further divided into two regions, namely "send 1" and "send -1", to increase the amount of information made available to the FC. Therefore, as compared with the conventional scheme, the advantages of the proposed censoring scheme can be intuitively interpreted that more information is provided to the FC, i.e., ternary instead of binary, while the energy consumption of the sensor reduces, i.e., the sensor node spends no energy on transmission to the FC when its observation falls into the silent region[15].. The performance of the proposed censoring scheme is examined in terms of the energy saving gain compared to the conventional scheme. The result confirms that the goal of energy saving by the proposed scheme is achieved. Especially, when the reliability of the observation made by the sensor on the environment is low, the energy saving attained by employing the proposed scheme becomes significant.

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