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Hybrid detection algorithm for online faulty sensors identification in wireless sensor networks

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Abstract: Wireless sensor network (WSN) is a developed wireless network consisting of some connected sensor nodes. The WSN is employed in many fields such as military, industrial, and environmental monitoring applications. These nodes are equipped with sensors for sensing the environmental variables such as temperature, humidity, wind speed, and so on. In most applications, WSN is positioned in remote places and harsh environments, where they are most probably exposed to faults. Hence, faulty sensor identification is one of the most fundamental tasks to be considered in WSN. This study suggests a hybrid methodology based on mutual information change (MIC) and wavelet transform (WT) for faulty sensor identification. The MIC method is suggested to study correlation among sensors, while the WT technique is proposed for self-sensor detection. WT is suitable for analysing non-stationary signals into approximation and detail coefficients. The suggested algorithm performance is investigated by applying a real case study at an arbitrary location close to Cairo, Egypt. The results of each method are compared using the true positive rate (TPR), false negative rate, and accuracy measures. Obtained results have shown that combining MIC and WT techniques can achieve a higher TPR and accuracy reach 100% in most fault types.

1 Introduction

The development of sensing abilities and wireless communication technologies has greatly increased, leading to the development of inexpensive and low power wireless sensor network (WSN) [1, 2]. WSN is an advanced system composed of a set of sensor nodes. The major function of each node is to sense, process information, and communicate this information to their neighbours [1, 3].

The main objective of designing a WSN is to monitor, detect, and provide useful information about network performance [4]. The architecture of a typical WSN is represented in Fig. 1. Sensor nodes may be grouped into clusters or cooperatively work together to complete a common task [3, 5]. In clustering, sensor nodes are divided into clusters. Each cluster has a leader node called a cluster head (CH). The CH is responsible for gathering the received data from the other remaining nodes, which act as cluster member nodes, hence, CH transmits the aggregated data to the sink node [5, 6]. Each node is equipped with sensor(s) that is/are responsible for sensing the surrounding environmental variables such as temperature, wind speed, wind direction, radiation etc. [7, 8]. In this research work, a study of the relationship among sensors' data using mutual information (MI) measure is proposed to identify faulty sensors in the network.

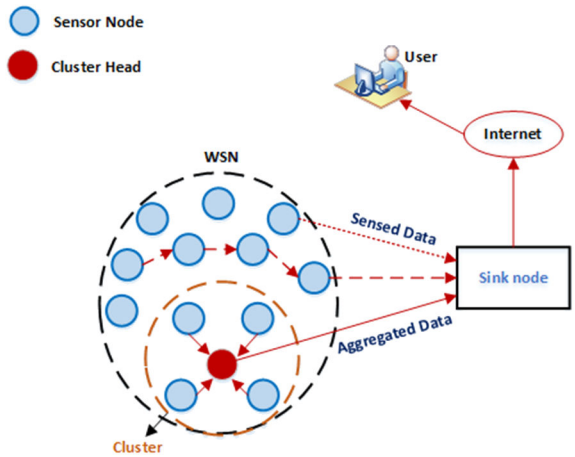

Fig. 1 *WSN architecture*

WSN has gained popularity in recent years [9]. It has major characteristics over wired networks such as remote sensing, low cost, rapid deployment, and self-organisation [10]. Due to these advantages, WSN is used in various applications such as animal tracking, health monitoring, and industrial applications [3]. Therefore, sensor recordings should be accurate to ensure reliable operation and avoid faulty data [11]. However, in most applications, the sensor nodes are deployed in harsh environments and unstable conditions that could affect the performance of the WSN [12]. In addition, the sensors are often influenced by noise, unwanted disturbance, such as electromagnetic interference, vibration, shot/flicker noise, and environmental noise [13]. Consequently, WSN is vulnerable to faults. A fault is an undesirable event that results in corrupted data affecting the quality of the system [14]. Therefore, the identification of faulty sensors in WSN is necessary [15]. Many fault detection algorithms have been proposed in the literature to overcome this problem. One of the suggested solutions to maintain the operation of the network, even if a fault is present [16], is to estimate missing data of faulty sensor at a certain area based on the data of other sensors at the correlated places as explained in [17]. More details about the work related to fault detection will be described in the literature review section.

The main objective of this paper is to develop a new hybrid methodology based on the mutual information change (MIC) method and WT technique to identify faulty sensors. The advantage of using the WT tool is that every sensor can be monitored separately. Moreover, it can determine the instantaneous fault. A comparison is done between both methods to evaluate the performance of each approach.

This paper is organised as follows: Section 1 introduces the motivations and defines the problem. Section 2 surveys the previous work related to fault detection. Section 3 describes an overview of information theory measures. Section 4 presents a new technique for signal analysis. Section 5 explains the proposed fault detection algorithm with a real case study. Section 6 discusses the simulation results of the selected scenarios, and finally, Section 7 concludes.