Power-Efficient Data Fusion Assurance Using Indirect Anti-Voting Mechanism in Wireless Sensor Networks

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Abstract: In Wireless sensor networks (WSNs), the sensors detect environmental variations and then transmit the detection results to other sensors or a Base Station. The collected data must be processed by some sensors, so as to reduce the transmission burden before transmitting the data to the Base Station. This process is called Data Fusion and the sensors performing data fusion are the fusion nodes. Although fusion significantly lowers the traffic between the fusion nodes and the Base Station, the fusion nodes are more critical and vulnerable to malicious attacks than non-fusion sensors. If a fusion node is compromised, then the Base Station cannot ensure the correctness of the fusion data sent to it. This work focuses on providing data fusion assurance, power efficiently. The new method portrayed here is the Indirect Anti-Voting Mechanism. A fusion node is selected at random for forwarding the fusion data as in the previous methods. But instead of sending the data, the fusion node sends an encrypted aggregate value to the Base Station. The Base Station decrypts and broadcasts the aggregate and waits for Anti-Votes from the fusion nodes which do not comply with the fusion result.

Key words: Data Fusion • Malicious node • Direct Voting • Aggregate • Indirect Anti-Voting

INTRODUCTION

Recent advances in electronic and computer technologies have paved the way for the proliferation of ubiquitous wireless networks. Fast deployment of communication networks is highly desirable under many situations, such as establishing efficient, survivable dynamic communications for emergency and rescue operations. While the Base Station can have continuous, unlimited power supply, the sensor nodes usually have limited power supply and are battery-powered [1]. It is inconvenient to replace once deployed in the field. Sometimes, replacement is even impossible. Thus energy efficiency is a critical design consideration of wireless sensor networks. In these networks, communication is a dominant source of energy consumption [2].

The aim is efficient transmission of all the data to the Base Station so that the lifetime of the network is maximized in terms of rounds, where a round is defined as the process of gathering all the data from sensor nodes to the Base Station, regardless of how much time it takes [3]. Direct transmission, a simple approach for this problem in which each node transmits its own data directly to the Base Station. However, if the Base Station is far away, the cost of sending data to it becomes too large and the nodes die quickly. Since large number of sensor nodes are densely deployed, neighbour nodes may be very close to each other. Multihop communication can effectively overcome some of the signal propagation effects experienced in long-distance wireless communication. Sensor nodes carry limited, generally irreplaceable, power sources. Therefore, while traditional networks aim to achieve high quality of service (QoS) provisions, sensor network protocols must focus primarily on power conservation [4]. By avoiding unnecessary transmissions, power consumption in a wireless sensor network can be very much reduced. This is made possible by Data Fusion. Data Fusion is the collection and processing of information from various sensors, before transmitting it to the Base Station, thereby reducing the amount of traffic. The data from a group of sensors (referred to as clusters) are collected at their corresponding clusterheads or fusion nodes. These fused data from the clusterheads are then transmitted either to the other clusterheads or sent to the

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command center (Base Station). The sensors do not communicate with one another, but the clusterheads can communicate with the other clusterheads. Thus, sensors and clusterheads are functionally different.

Thus data Fusion reduces the traffic load, conserves energy of the sensors and reduces the redundancy in the data at the Base Station [5, 6]. Even though this data collection and processing architecture drastically relieve the communication burden on the network, the nodes conducting data fusion are vulnerable to attacks. Data fusion is usually implemented over the network. Since the sensor is typically placed in locations accessible to malicious attackers, information assurance of the data fusion process is very important. If a data fusion node is compromised, it can send bogus data to the Base Station. Thus, the fusion results must be the same. This work assumes that this problem has been solved. The second problem is concerned with the assurance of the fusion result. The transmission between the fusion node and the Base Station is assumed herein to be error-free. Since some fusion nodes may be compromised, the fusion node chosen by the Base Station to transmit the fusion result may be one of the compromised nodes. Malicious data may be sent by the compromised node and the Base Station cannot discover the compromised nodes from the normal fusion nodes, since the data detected by the sensors are not sent directly to the Base Station. Consequently, the result obtained at the Base Station may be incorrect [9].

Existing System

Witness Based Approach: Du et al. [10] used the “witness” concept to solve the assurance problem between data fusion nodes and the Base Station. Du et al. presented a Witness Based Approach to ensure the correctness of the fusion result. One of the fusion nodes is chosen to transmit the fusion result to the Base Station. All the other fusion nodes, act as witnesses of the transmitted fusion result. Several fusion nodes are used to fuse the collected data and have the ability to communicate with the Base Station. Witnesses, encrypt the fusion results to Message Authentication Codes (MACs). (Figure 1) The MACs are then sent to the Base Station through the chosen fusion node. Finally, the Base Station utilizes the received MACs to verify the received fusion data. A long MAC increases the reliability of the verification. However, the transmission of the long MAC imposes a high communication burden. If the received fusion result at the Base Station cannot pass the verification, then a polling scheme is started to determine whether any valid fusion result is available at the other fusion nodes.

Demerits:

Long MAC’s are an overhead
Many copies of the fused data are sent to the Base Station. Not Power efficient.
Direct Voting Mechanism: Hung-Ta Pai and Yungkin Y. S. Han [9] proposed a new scheme to ensure data fusion assurance. This method is better than the witness-based method (Figure 2). The Base Station obtains votes contributing to the transmitted fusion result directly from the witness nodes. Only one copy of the correct fusion data provided by one uncompromised fusion node is transmitted to the Base Station. No valid fusion data are available if the transmitted fusion data are not approved by a pre-set number of witness nodes. The witness node overhears the transmitted fusion result from the chosen node. It then compares the overheard result with its own fusion result. Finally, the witness node can transmit its vote on the overheard result directly to the Base Station, rather than through the chosen node. When a fusion node wishes to send its fusion result to the Base Station, it adopts the group key to encrypt the result and other fusion nodes serving as witness nodes can decode the encrypted result. The witness node then starts to vote on the transmitted result. A Polling Scheme based on the voting mechanism using a public key is proposed to ensure data fusion assurance.

Demerits: The Polling Scheme is an overhead. Use of a public key is a threat to security.

Proposed System: This work proposes a novel Power-Efficient Data Fusion Assurance Using Indirect
Anti-Voting Mechanism. If several copies of the fusion data are sent to the Base Station, power consumption for data transmission is very high. Hence in this method, instead of sending the entire set of fused data, only the aggregated value of the data collected is transmitted to the Base Station. The proposed mechanism adopts the public-key cryptography [7]. The method makes use of set of keys as discussed below. In the proposed method, a fusion node is selected at random for forwarding the fusion data as in the previous methods. But, instead of sending the data, the fusion node sends an aggregate value to the Base Station, by encrypting it with the $K_i$, where

$$K_i = \text{private key of the fusion node} \oplus \text{public key of the Base Station} \quad (3.1)$$

Data after encryption = data from the sender $\oplus K_i$ \quad (3.2)

- The Base Station waits for Anti-Votes from the selected fusion node to the Base Station. Power is preserved at the other fusion nodes. In the Witness Based Approach, many copies of the fusion data (MAC) are sent to the Base Station and in the Direct Voting Mechanism one encrypted copy of the fusion data is made available at the Base Station. In the existing methods this copy of the data has to be approved by other witness nodes. Only then will the Base Station accept the fusion data [12, 13]. In case the Base Station rejects the data, copy/copies of the fusion data at the Base Station is a transmission overhead. In this proposed method, this is avoided by initially sending the aggregate value to the Base Station and then sending the fusion data only when the Base Station makes a request. Since the transmission of fusion data consumes a lot of energy, obviously the proposed method reduces the transmission overhead and thereby power consumption. This system avoids re-transmission also. Since Anti-Voting mechanism is used, power is spent only for Anti-voting, (i.e) if and

$$\text{Data after encryption at the receiver} = \text{data at the receiver} \oplus K_i \quad (3.3)$$

- The Base Station broadcasts the aggregate value after encrypting it with a key $K_2$
- The Base Station receives the encrypted value, decrypts it with key $K_2$, where

$$K_2 = \text{private key of the Base Station} \oplus \text{public key of the Fusion node} \quad (3.3)$$

- The Base Station waits for Anti-Votes from the selected fusion node to the Base Station. Power is preserved at the other fusion nodes. In the Witness Based Approach, many copies of the fusion data (MAC) are sent to the Base Station and in the Direct Voting Mechanism one encrypted copy of the fusion data is made available at the Base Station. In the existing methods this copy of the data has to be approved by other witness nodes. Only then will the Base Station accept the fusion data [12, 13]. In case the Base Station rejects the data, copy/copies of the fusion data at the Base Station is a transmission overhead. In this proposed method, this is avoided by initially sending the aggregate value to the Base Station and then sending the fusion data only when the Base Station makes a request. Since the transmission of fusion data consumes a lot of energy, obviously the proposed method reduces the transmission overhead and thereby power consumption. This system avoids re-transmission also. Since Anti-Voting mechanism is used, power is spent only for Anti-voting, (i.e) if and

$$\text{Data after decryption at the receiver} = \text{data at the receiver} \oplus K_2 \quad (3.4)$$

- The Base Station waits for Anti-Votes from the selected fusion node to the Base Station. Power is preserved at the other fusion nodes. In the Witness Based Approach, many copies of the fusion data (MAC) are sent to the Base Station and in the Direct Voting Mechanism one encrypted copy of the fusion data is made available at the Base Station. In the existing methods this copy of the data has to be approved by other witness nodes. Only then will the Base Station accept the fusion data [12, 13]. In case the Base Station rejects the data, copy/copies of the fusion data at the Base Station is a transmission overhead. In this proposed method, this is avoided by initially sending the aggregate value to the Base Station and then sending the fusion data only when the Base Station makes a request. Since the transmission of fusion data consumes a lot of energy, obviously the proposed method reduces the transmission overhead and thereby power consumption. This system avoids re-transmission also. Since Anti-Voting mechanism is used, power is spent only for Anti-voting, (i.e) if and
Fig. 3: Indirect Voting

Fig. 4: Graph showing the transmission load (1) when the fusion data, anti-votes and votes are sent (2) when the aggregate and both anti-votes and votes are sent (3) when the aggregate and only anti-votes are sent only if there is an invalid aggregate at the Base Station. So the power at the Fusion nodes is not wasted for Voting/Anti-Voting during normal operations.

CONCLUSION

Power consumption plays a vital role in wireless sensor networks. So this work conserves power to a greater extent by reducing the unnecessary transmissions. The amount of traffic in the network is very much reduced as only the aggregate value is transmitted instead of the entire set of the fusion data. Only on request by the Base Station will the fusion data be sent to it. Further only Anti-votes are sent. Further to avoid the compromise of the fusion nodes each node has its own private and a public key. Here the keys are not transmitted in the network. So the attacks and the corruption of the keys are avoided. To crown it all, this proposed method provides a secured transfer of data as well as avoids retransmission.

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