Weighted Aggregation Scheme with Lifetime-Accuracy Tradeoff in Wireless Sensor Network

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We consider design of wireless sensor network for event detection application. An MMSE based $q$-bit weighted aggregation scheme ($q$-WAS) is proposed in which each node transmits $q$ bits to its parent in every session. The observation of each sensor is assumed to be one bit. The simulation results show that 1-WAS achieves better accuracy than a previously proposed one bit aggregation scheme while offering almost same lifetime. With increasing $q$, the accuracy of $q$-WAS approaches that of the infinite precision aggregation scheme. Moreover, the lifetime for $q$-WAS is significantly higher than infinite precision aggregation scheme. For a 100 node sensor network, the simulation results show that 3-WAS achieves a near optimum accuracy. The lifetime of the $q$-WAS is approximately $1/q$-th of the lifetime of the one bit aggregation schemes. Hence this class of aggregation schemes offers a trade-off between accuracy and lifetime.

1. INTRODUCTION

Wireless Sensor Network (WSN) [1] has come into existence with the development of low cost, low power and small size sensor nodes. These sensor nodes can sense, process and communicate information amongst themselves to collaboratively perform a particular task. WSN is an emerging technology that has already proved its applicability in surveillance, precision agriculture, smart home, industry, habitat monitoring, disaster control etc. For any application, energy is the major constraint in the design of WSN. Hence network lifetime becomes an important performance evaluating parameter.

We consider event detection application using wireless sensor network. Sheth et al. [2] explored the use of WSN for landslide detection which is a more specific case of event detection. Also WSN is found to be useful in applications like the detection of volcano, earthquake, fire etc [3–5].

A rich literature on distributed detection is available [6–15] which primarily considers decision fusion for event detection or target detection applications. Moreover, they all consider sensors with one bit sensing capability which decides about the occurrence/non-occurrence of the event or the presence/absence of the target depending upon the application. The information sensed by these sensors is further communicated to the fusion center which makes the final decision.

Distributed detection using multiple sensors with various network topologies were considered in [8,9], where the observation of each sensor and the communication to its parent was considered to be 1-bit. [6,10,11] consider target detection application in which local sensors have different performance indices, measured in terms of probability of detection and the probability of false alarm. [6] considers the presence of fading channel along with local sensor performance indices. It assumes the instantaneous channel state information (CSI) and performance indices of local sensors to be known at the fusion center. Based on this information and the received 1-bit decisions from sensors, the fusion center makes the decision using either optimum likelihood ratio based fusion rule or any of the suboptimal fusion rules. Suboptimal fusion rules discussed in [6] are the Chair-Varshney fusion rule, Maximum Ratio Combiner (MRC) and Equal Gain Combiner (EGC). While all these decision fusion rules try to increase the performance in terms of system level probability of detection ($P_D$) and system level probability of false alarm ($P_F$), certain
4. DISCUSSION

The assumption of a static network can be relaxed and the network may be made self-organizable. The only modification in the algorithm will be to keep track of the change in topology due to the nodes which die out and get eliminated from the network and cause change in the number of descendants $N_i$ for all its ancestors. The $N_i$’s may be updated every few sessions and the corresponding mean values recomputed if the full matrix of mean values is not stored in the sensors. Alternatively, whenever a node’s $N_i$ has changed, it may communicate the information to its parent with some extra bits. To keep the network alive even after some nodes die, the routing itself needs to be redone to make it more efficient for the changed topology. In the schemes $M1$ and $q$-WAS all the nodes transmit and receive approximately same number of bits and also, once nodes start dying, remaining nodes transmit with more power to communicate over larger distance. Thus all the nodes die soon after the first node dies.

5. CONCLUSION

A $q$-bit MMSE based Weighted Aggregation Scheme ($q$-WAS) is proposed for event detection application using wireless sensor network. One bit WAS (1-WAS) shows better accuracy as compared to the previously proposed one bit scheme $M1$, with almost same lifetime. Simulation results show that the accuracy of 3-WAS almost reaches near that of the infinite precision aggregation scheme. The lifetime of the $q$-WAS is approximately $1/q$th of the lifetime of the 1-bit aggregation schemes. However, it is observed that it is still significantly higher than that of the infinite precision aggregation scheme for small values of $q$. Simulation results again show that for $M = 100$ the lifetime of 3-WAS is significantly better that that of the infinite precision aggregation scheme. $q$-WAS allows the lifetime-accuracy trade-off for the event detection application by simply varying the number of transmitted bits $q$. This can be viewed as a simple knob available which can increase or decrease the resolution at the cost of
power. In practice, one can use 1-WAS normally and in case the event is detected, $q$-WAS can be used subsequently with higher $q$ for more precise detection.

REFERENCES


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