CHAPTER 7

CONCLUSION AND FUTURE WORK

Advances in micro-electro mechanical systems technology have enabled the design of smart sensors, equipped with multiple functions such as sensing, computing and communication. Such intelligent sensors are networked through wireless links, and are called wireless sensor networks. WSNs are recognized as one of the most important technologies for the 21st century. Wireless sensor networks also hold the promise to revolutionize the sensing technology for a broad spectrum of applications, including infrastructure monitoring, surveillance and disaster management, where the detection ability of the WSN is crucial.

In this research work, some important aspects of decentralized detection in wireless sensor networks have been addressed, making contributions to both the theory and practice of this research topic. A central theme throughout this thesis is the investigation of the detection performance of a WSN designed with the Neyman-Pearson design criterion.

The detection problem provides a productive starting point for the study of more general statistical inference problems in sensor networks. A survey of the classical framework for detection is presented in Chapter 2. However, the classical framework does not consider the important features of sensor technology, and of the wireless communication link between the sensors and the fusion centre. A review of the alternative frameworks for detection in sensor networks that have emerged over the last few years is
provided in the same chapter; and this can give an understanding of the
detection problems in sensor networks. Distributed detection in a wireless
sensor network is a relatively nascent field, and a complete theoretical
framework is still in the developmental stage.

Based on a fair-sized sample of recent scientific WSN articles, it
has been observed that about 75 % of the research work is carried out on
topics such as deployment, target tracking, localization, data gathering,
routing and aggregation, security, MAC protocols, querying and databases,
time synchronization, applications, robust routing, lifetime optimization,
hardware, and distributed algorithms. However, surprisingly, research on
detection and estimation is only about 1.21%. This suggests that relatively
more work needs to be done in this area.

Chapter 3 focuses on the design approaches to wireless sensor
networks for the detection of ionizing radiations from signal processing
perspectives. In this chapter, the performance of the WSN designed for
radiation detection using the Neyman Pearson methodology is investigated.
The detection performance of the individual nodes and networks of sensor
nodes under two different operating options for different network parameters
and sensor characteristics has been examined, and the results are presented to
show the constraints and design trade offs that apply to the real world
deployment of sensor nodes with radiation detection instruments.

The robustness of the two detection schemes against node failure is
assessed, and it is observed that the loss of performance in terms of ratio of
increase in error probability is lower for decentralized detection, when
compared to centralized detection.

The results stated could give an additional insight for the optimal
design of WSNs for radiation detection applications. This study does not
consider the physical characteristics of containment systems that are designed to prevent the release of radiation into the environment. Further performance analysis considering the photon absorption rate in the medium will be worth investigating. An extension of this analysis to non ideal communication medium will be more useful.

In Chapter 4, the performance of distributed detection systems employing a set of geographically separated, deterministically deployed sensor nodes is investigated. The performance of the detection system is analyzed, considering node fault behavior and channel error, imposed by wireless channel characteristics. The required threshold for a given false alarm probability and the corresponding probability of detection for sensor nodes and the overall system are determined. The node level and system level ROC curves are provided to compare the detection performance of the given system and the channel parameters.

The results given could provide an insight for the optimal design of WSNs for event detection applications. However, this study does not consider the interference due to other networks operating in the same frequency band. Further performance analysis considering the interference in the medium and measurement noise will be worth investigating. An extension of this analysis to other fading channels will be more useful.

In Chapter 5, the detection performance of WSNs is studied with reference to the binary hypothesis, in which a number of identical and static sensor nodes transmit their binary decisions to a fusion centre. It is assumed that the transmission channel is unreliable due to the presence of channel fading and noise. Multipath fading contributes heavily to the unreliability of wireless links. The analytical results on the detection performance of WSNs show that the measurement noise and channel characteristics have a significant effect on the detection performance. The fusion centre is
considered to employ the Neyman Pearson test on the decisions reported by
the local sensors. Each link between a sensor and the fusion centre is
modelled independent and identically distributed as slow fading.

The performance of a WSN is characterized, using the receiver
operating characteristics (ROC) illustrating the global false alarm rate and
the corresponding achievable probability of detection, and this provides the
design engineer with an insight to select the optimal design parameters. In
this work, the Rayleigh, Ricean, Nakagami and Weibull fading environments,
that have practical significance in the real world deployment of sensor
networks are considered. Further, the system performance is compared with a
similar system employing the threshold-OR fusion rule.

The results give us an idea for the design of WSNs for event
detection in a non-ideal communication medium. This study does not
consider the interference and sensor fault behaviour. Further performance
analysis considering the interference in the medium and the sensor fault
behaviour will be worth investigating. An extension of this analysis to other
fusion schemes will be more meaningful.

In Chapter 6, the problem of distributed detection over a wireless
fading channel is considered. The communication aspect of distributed
detection is analyzed, and a DC-MAC protocol is introduced for WSNs, that
exploits the collaborative nature of sensors. The detection performance of the
Neyman Pearson detector adopting this constructive interference MAC
scheme is investigated under different network conditions. The error
exponent, which is a function of mean transmissions and channel coherence
index is characterized, which is a valuable guide, as a network designer
pursues practical solutions. This characterization seems to give the correct
insight into an optimal design. The results show that there exists an optimal
mean transmission that minimizes the error probability. This gives a sensor
activation strategy, that achieves an optimal allocation of transmission energy to spatial and temporal domains. It is also observed that the optimal TBRA scheme performs better than the conventional TDMA scheme.

Certain technical issues such as synchronization need to be addressed before these schemes can be exploited effectively. Further, authentication and encryption cannot be applied easily to transmissions, while using the constructive interference scheme.

With the ever-increasing popularity of wireless sensor networks and their tremendous potential to impact multiple aspects of our lives, this research work is timely, and addresses the needs of a growing community of design engineers and, network professionals.