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Channel-aware distributed detection in wireless networks with correlated observations

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Abstract

We study data fusion in a distributed detection system, consisting of several sensors and a fusion center (FC), that is tasked with solving an underlying binary hypothesis testing problem (e.g., detection of a signal source or a target in a field being monitored). Each sensor makes a binary local decision based on its local observation, where these local decisions are digital modulated and transmitted over wireless channels to neighboring sensors and/or the FC. A global binary decision is made at the FC by fusing the data received from sensors. But due to additive Gaussian noise and multipath fading, effect of wireless communication channel, the binary local decisions are corrupted, causing the global decision to be less reliable. Our goal is to maximize the reliability of the global decision. We ask the question: what is the optimal distributed detection system design in the presence of multipath fading and additive Gaussian noise in wireless communication channel? To address this question in this thesis, we identify and address two subproblems as the following:

P1) We propose a new class of integrated distributed detection, which harvests cooperative gain (enabled by at most 1-bit information exchange among one-hop neighboring nodes) and improves the performance of the integrated distributed detection in the presence of fading, via pushing the communication bounds. In particular, we propose three schemes: (i) cooperative fusion architecture with Alamouti's space-time coding (STC) scheme at sensors, (ii) cooperative fusion architecture with signal fusion at sensors, and (iii) parallel fusion architecture with local threshold changing at sensors. For these schemes, we derive the likelihood ratio test (LRT) and majority fusion rules at the FC, and provide upper bounds on the average error probabilities for homogeneous sensors, subject to uncorrelated Gaussian sensing noise, in terms of signal-to-noise ratio (SNR) of communication and sensing channels. Our numerical results show that, when the FC employs the LRT rule, unless for low communication SNR and moderate/high sensing SNR, performance improvement is feasible with the new cooperative and parallel fusion architectures, while scheme (iii) outperforms others. When the FC utilizes the majority rule, such improvement is possible, unless for high sensing SNR. In particular, for very high sensing SNR scheme (i) outperforms, whereas for moderate/low sensing SNR scheme (ii) outperforms others.

P2) We consider the problem of detecting a Gaussian signal source, where the observations at sensors are correlated samples of signal source corrupted by additive Gaussian sensing noise. Imposing either total or individual transmit power constraints at sensors, assuming linear data fusion at the FC, and different communication multiple access channel schemes (to enable communication between sensors and the FC), we study the optimal power allocation corresponding to coherent and noncoherent reception at the FC. We also study how the spatial correlation among sensors' observations degrades the reliability of global decision of the system and affects the power allocation of inhomogeneous sensors.