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Convergence Rate Analysis of Distributed Gossip (Linear Parameter) Estimation: Fundamental Limits and Tradeoffs

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The paper considers gossip distributed estimation of a (static) distributed random field (a.k.a., large scale unknown parameter vector) observed by sparsely interconnected sensors, each of which only observes a small fraction of the field. We consider linear distributed estimators whose structure combines the information \emph{flow} among sensors (the \emph{consensus} term resulting from the local gossiping exchange among sensors when they are able to communicate) and the information \emph{gathering} measured by the sensors (the \emph{sensing} or \emph{innovations} term.) This leads to mixed time scale algorithms--one time scale associated with the consensus and the other with the innovations. The paper establishes a distributed observability condition (global observability plus mean connectedness) under which the distributed estimates are consistent and asymptotically normal. We introduce the distributed notion equivalent to the (centralized) Fisher information rate, which is a bound on the mean square error reduction rate of any distributed estimator; we show that under the appropriate modeling and structural network communication conditions (gossip protocol) the distributed gossip estimator attains this distributed Fisher information rate, asymptotically achieving the performance of the optimal centralized estimator. Finally, we study the behavior of the distributed gossip estimator when the measurements fade (noise variance grows) with time; in particular, we consider the maximum rate at which the noise variance can grow and still the distributed estimator being consistent, by showing that, as long as the centralized estimator is consistent, the distributed estimator remains consistent.

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