

Bounds on Wireless Location Estimation of Mobile Transmitters in a Time Varying Acoustic Underwater Channel

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Abstract: Wireless localization of multiple mobile underwater transmitters has become a very important area of research. Applications of location algorithms can be used to configure optimal routing protocols to allow intercommunication between various underwater nodes uniformly distributed in a given volume V . Several solutions to the underwater localization problem consider the measurement of the first time of arrival of a signal coming from a node with unknown location and arriving at a receiver with known location. This allows the estimation of distance between them and eventually, the estimation of the node location by triangulation. The measurements of the first time of arrival can be inaccurate if the signal transmissions occur in time varying multipath channels. Previous work has presented estimators that use the received signal strength indicator (RSSI) for the location of a node in a channel that contains only large-scale fading effects (i.e. power attenuation due to distance). In this work we extend those results to account not only for large-scale fading but also for small-scale fading (i.e. time varying multipath). Small-scale fading accounts for received signal fluctuations in repeated measurements at the same inter-node distance. Further, due to the addition of a small-scale fading model, the necessary assumption

of independent log-normal fades among successive measurements is removed, enabling multiple measurements at the same location. Using this combined statistical model we produce Cramer-Rao bounds on the estimation error for inter-node range. We obtain these bounds using RSSI measurements, then we use a different statistic, the raw sampled received signal, to show the effects of using power measurements instead of instantaneous received signal samples. The bounds on ranging error between nodes are then related to network localization time of $N+Q$ nodes, uniformly distributed in a volume V . Consider a scenario where we have Q transmitters with known locations, and N whose locations are unknown at time $t=0$. Define the time $T(R,Pr)$ as the first time when all N nodes know their location with a confidence Pr to be within a sphere of radius R . Further, we define E_Q as the total energy expended by the Q transmitters for localization, and E_N as the energy expended by the nodes of unknown initial location. The localization bounds found in this work will allow the calculation of the moments of $T(R,Pr)$, E_Q and E_N as a function of the network parameters N , Q , V , R , Pr . These moments may then be used in the design of better performance location-aware routing protocols.