

# Improvement of Location Accuracy by Adding Nodes to Ad-Hoc Networks

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**Abstract** We discuss the effect of adding nodes on the location accuracy of Ad-Hoc networks. All results are obtained by analyzing the Cramér-Rao Lower bound. We show that for planar network the additional node must have at least 3 connections in order to have any effect on the existing nodes accuracy. Further, we identify the nodes whose accuracy will be improved. Finally, we show that the accuracy cannot be improved without limit by adding more and more nodes to an existing network.

**Keywords** Wireless sensor network · Location estimation · Ad-Hoc networks · Maximum likelihood estimation · Cramér-Rao bound

## 1 Introduction

Location estimation of nodes within a network is considered. It is assumed that incomplete and inaccurate range measurements are provided for this purpose. Many publications proposed localization algorithms. Some representative papers are [1–13]. Applications of sensor networks include environmental sensing (temperature, barometric pressure, humidity, etc.), water quality monitoring, inventory management, traffic monitoring, herd control, wild life behavior studies and many more. It was noted in [3] that usually when adding a node to a network with enough connections the accuracy of localization improves. Here we explore this observation and find the conditions that guarantee improvement. The work is based on close examination of the Cramér-Rao lower bound. We have shown in a previous publication, [13], that the Maximum Likelihood estimator approaches the bound when the ranging error is small enough. One might get the impression that as more and more nodes are added to the network the localization accuracy improves without limit. However, there is a limit that is

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