In the location estimation phase, measurements are aggregated and used as inputs to a localization algorithm. In this section, first we describe the distinction between noncooperative and cooperative localization algorithms. Then we explain the localizability issue arising within the cooperative localization and elaborate the graphical issues in the localizability problem.

**Noncooperative Versus Cooperative:** In a noncooperative (one-hop) localization approach, there is no communication between ordinary nodes, only between ordinary nodes and anchors. Every ordinary node needs to communicate with multiple anchors, requiring either a high density of anchors or long-range anchor transmissions as shown in Fig. 1.

![Fig. 1. Noncooperative (one-hop) localization.](image)

In cooperative (multi-hop) localization, we still allow ordinary nodes to make measurements with anchors, but in cooperative localization, we additionally allow ordinary nodes to make measurements with other ordinary nodes as shown in Fig. 2. Internode communication removes the need for all nodes to be within communication range of multiple anchors. Thus high anchor density or long-range anchor transmissions are no longer required. The additional information gained from these measurements between pairs of ordinary nodes can offer increased accuracy and coverage.

A formal statement of the “cooperative localization problem” is given by Patwari et al. in [3]. Consider a sensor network \( S \) consisting of a set of \( m > 0 \) nodes labeled 1 through \( m \) that represent anchor nodes together with \( n - m > 0 \) additional nodes labeled \( m + 1 \) through \( n \) that represent ordinary nodes. Let measurements \( \mu_{ij} \) between certain pairs of nodes \( s_i, s_j \) be given, and suppose the coordinates \( p_i \) of the anchor nodes \( s_i \) are known. The **cooperative localization problem** is finding the coordinates of the ordinary nodes such that the assignment of the coordinates of ordinary nodes is consistent with the measurements \( \mu_{ij} \) and is consistent with anchor node coordinates. The corresponding framework of the cooperative sensor network is shown in Fig. 3.

We note that graph structure naturally arises in representation of cooperative networks.

Cooperative localization algorithms can be generally divided into “centralized algorithms,” which collect measurements at a central processor prior to calculation, and “distributed algorithms,” which require sensors to