the histogram that 246 sensor out of 250 are localized with absolute estimation error less than 2.5 measurement unit.

Figure 10 shows a different scenario where the grid is 100X100 units and the density is 80 sensors with only 10% Anchors (8 Anchors) with transmission range between (5 and 35 unites). The unlocalized nodes that have enough Anchor neighbors (3 at least), will become later virtual Anchors and will aid in the localization process of the others. It is clear that TALS is a very good algorithm even with small number of initial Anchors.

In the following sections, we will examine carefully the effects of different parameters on the overall performance.

5.3. Effect of Anchor density

The anchor ratio is one of the most important factors affecting localization accuracy. Thus, we report accuracy and performance results with a varying number of anchor nodes. Since the ratio of the anchor nodes is controlled by the fixed number of sensor nodes deployed in the sensor field, the number of normal nodes is decreased if the number of anchor nodes is increased. In this case we are more interested in the performance when the anchor ratio is small because in a practical system the number of anchor nodes will be much lower than the number of unlocalized nodes. Figure 11 shows that different anchor ratios will influence the amount of location errors. One can see that with the same node density at the same deployment area, when the percentage of initial anchors is increased from 20% to 30%, the average localization errors decrease significantly. Our algorithm performs well as it manages to produce small error, even without large numbers of Fixed anchors as clearly shown also in Fig. 10.

5.4. Effect of Node density

Our second goal from the simulation is to determine the effect of node density on the localization success ratio and the average of localization error. For this experiment, we gradually increase the number of nodes from 80 to 220 in the same network area. As the number of nodes grows, the node density increases, and the number of derived anchors increases too. As depicted in Fig. 11(a), we found that as we increase the node density, the localization success ratio gets higher as expected. The question that has been answered here is: what is a good initial fixed anchor ratio to achieve certain accuracy level or localization error. We conclude that nodes benefit from more neighbors and redundancy. Also, that the error propagation of ordinary nodes becoming derived anchors and aiding other nodes in the localization process are within acceptable range.

5.5. Localization under noisy distance measurements

In this simulations, the noisy range measurements are generated randomly and the distance error variation has a maximum of 5% of the actual distance between nodes. As shown in Fig. 11(b), the localization error is plotted against the ranging measurements error. With the increase of ranging errors, the localization accuracy is affected. However, with small noise range measurements, the influence is still negligible in the proposed optimized TALS contradicting many known localization systems.

5.6. Impact of transmission range

Figure 12 shows that TALS performs better at high transmission ranges where the unlocalized nodes benefiting from more Fixed and Virtual Anchors. The percentage of Fixed anchor nodes is kept fixed at 20% and the transmission range in the simulation varies between 10–50 units. Note that for the smallest transmission range available (10 units), the average error is small because many nodes will not be localized (less than three Anchor or virtual neighbors nodes are found) and has no error to be counted. With larger transmission range, more nodes (and potentially all) will be localized and their errors will start to be counted. However, as we increase the transmission range (above the value that permits most nodes to be localized), average localization error decreases. In addition, with the increase of the network density, the error decrease in a slow rate.