Popular Science Summary

The internet of things (IoT) is the infrastructure that enables the connectivity of smart devices to the internet. It has been estimated that around 100 billion devices will be connected by 2025 and this fast growth is expected to revolutionize many industries, such as healthcare, transportation, and agriculture. As of today, many everyday items are already being connected in smart home applications. Due to the wide range of applications, there are many different emerging standards for enabling the IoT. Narrowband IoT (NB-IoT) is a cellular technology that will allow connectivity for devices in remote areas while allowing for very long battery lifetimes, which is critical in some applications.

In the next release of NB-IoT, a new feature has been added that will allow positioning of devices by allowing them to receive signals from several cell towers simultaneously. Examples of applications of this feature are fleet management, network capacity planning, and navigation services. The used positioning technique is known as observed time difference of arrival (OTDOA), because the device measures the arrival time of several transmitted reference signals. By using the difference between the observed arrival times, the position of the device can be estimated. However, this technique has several limitations which makes it difficult to obtain good position accuracy. Since NB-IoT is technique that focuses on low-end devices, there has been a trade off where system capacity has been sacrificed in order to achieve low complexity. Therefore it is especially challenging to implement OTDOA-based positioning in NB-IoT. For example, the bandwidth of the reference signals is very small, which makes it difficult to locate them in time. Furthermore, the large distances covered by NB-IoT cell towers causes the received signal powers to be very weak. Smart techniques are therefore necessary in order to correctly locate an NB-IoT device.

In this thesis, a low-complexity OTDOA-based positioning algorithm that strives to overcome the challenges of NB-IoT networks has been implemented. The algorithm improves the positioning accuracy by cancelling interfering signals from neighbouring cell towers, estimating the frequency offset of each received signal and converting the results to a higher sampling frequency. Such methods have been used on their own in other cellular technologies, whereas in the algorithm proposed in this thesis, they are combined and applied to the specific scenario of positioning for NB-IoT. It is shown that the new algorithm increases positioning performance significantly compared to conventional methods. In particular, the

probability that a given user equipment can be localized is greatly increased, as well as the accuracy of the estimated position. Furthermore, an analysis of the computational complexity of the algorithm shows that it can be realistically implemented in user equipment hardware and software. However, the performance increases are not as great in urban environments where signals can scatter on buildings and other large objects, and this is an area of development for future work.