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Subject Area	Wireless Communications
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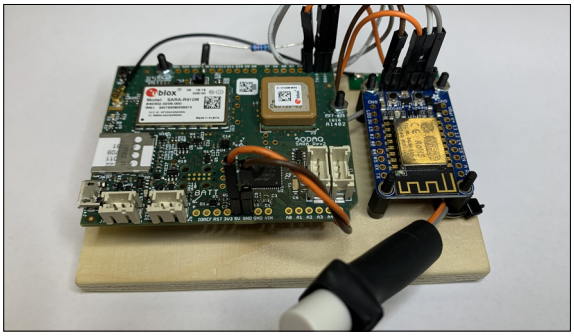
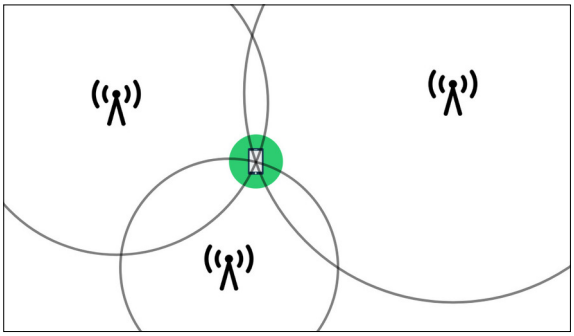
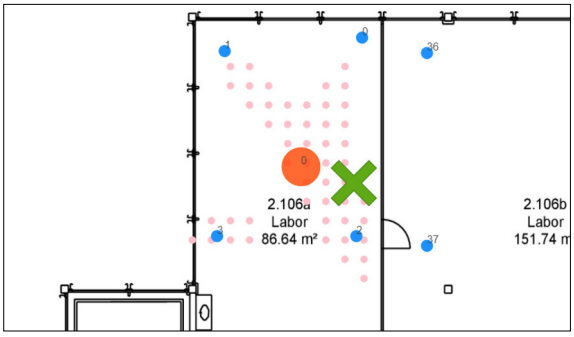
Indoor Localisation



The NB-IoT development kit with the WLAN module.
Own presentment



An illustration of a triangulation using cellular network antennas.
Own presentment



Map of a localisation with WLAN fingerprinting. Green cross: actual location. Red dot: calculated location.
Own presentment

Initial Situation: Localisation techniques play a major role in our everyday lives, for example while driving a car. These systems (e.g. GPS) are quite accurate. But the big disadvantage is that their signals can not penetrate buildings. On the other hand do a lot of indoor localisation techniques come with different disadvantages, like the need of a base station. This thesis tries to come up with a solution for this problem using existing infrastructure. Multiple approaches are tested. The goal is to develop a system with a portable demonstrator.

Approach: With the help of a NB-IoT development kit and a WLAN module, three different techniques are tested.
The first technique uses the NB-IoT network, which is a sub network of the LTE (4G) network and is laid out for Internet of Things (IoT) devices. It features better building penetration due to its lower frequency bandwidth than regular LTE. With the help of triangulation a localisation should be feasible. It calculates the position based on the distance to at least three different base stations.
A different approach uses the immense density of WLAN access points on our campus for a localisation. Based on those access points, two different techniques were evaluated.
The first technique utilizing WLAN is triangulation as well.
The other applied technique is fingerprinting. There are two separate steps necessary for fingerprinting. An offline phase to create a measurement database of the available access-points is the first step. The second step is the online phase to estimate the position.

Result: Unfortunately the NB-IoT network does not support switching between different base stations yet. Neither the determination of the distance with the given functions of the module was possible. Therefore a successful triangulation is not possible and this approach was cancelled.
Due to distortions, a WLAN triangulation was also not practicable. The distance can not be determined precisely because of walls and other objects in indoor environments. It would require additional measurements and calculations to extract them. The prospects of success were higher with fingerprinting, therefore this approach was also not further pursued.
Fingerprinting on the other hand turned out to be successful. An offline WLAN map of the second floor of HSR Building #2 was created. It includes the signal strength at certain points, which were then interpolated to generate a grid. In the online phase the device measures the visible access points with their corresponding signal strength. These measurements then get compared to the grid points to determine the location.
Several tests showed that this method achieves a mean error of 4.5 meters.