Accurate Node Localisation with Directional Pulsed Infrared Light for Indoor Ad Hoc Network Applications

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We present a localisation scheme for indoor ad hoc networks which use pulsed infrared light as the communication medium. Data transmission with infrared light has shown great potential for various applications such as ambient intelligence or indoor broadband communication systems. Infrared light has very attractive properties for indoor applications as it is inherently secure due to the fact that infrared signals do not penetrate walls. This property also reduces the interference and increases available bandwidth to individual devices. Infrared systems can be built with low-cost components, and are thus suitable for inexpensive consumer applications.

Localisation in wireless ad hoc networks is important since it allows the nodes to learn their precise location, and use this information for various self-organisation algorithms. These include topology configuration, fault tolerance, routing, mapping of measured data to physical locations, or support for mobile devices. The dissemination of accurate localisation information allows nodes to interact more intelligently with their environment and other nodes in the network.

Typically, in wireless ad hoc networks, nodes estimate their position relative to their neighbours by processing the location information, and certain physical properties of the signal they receive, such as signal strength, bit error rate, or time difference of arrival. Unfortunately, widely used low-cost infrared transmitters and receivers for indoor applications do not allow measurement of these properties easily. To overcome this, we have developed a system which relies only on the reception of a data frame and is capable of estimating the angular direction of the infrared signal source within an error margin of +/- 5 degrees. Then, through the application of triangulation, a node estimates its relative position with respect to its neighbours. One effective method of translating a relative location to an absolute one is to use anchor nodes. These nodes know their exact location and broadcast this information to their neighbours. Each node then progressively fixes its position and broadcasts the position updates, leading to the entire network localising itself. A major drawback of this approach arises in large networks, where the average hop distance between an anchor and ordinary nodes is large, and position estimation errors inevitably start to accumulate. In order to alleviate this problem, we have developed the Anchor Hop Distance Weighted Localisation (AHDWL) algorithm to selectively weigh position estimates at each hop. We have found that the AHDWL algorithm is very effective in reducing propagation of positioning errors.

A test network using directional pulsed infrared light was created to evaluate the performance of the localisation system. In addition, a simulator based on the experimentally obtained channel characteristics was developed for rapid evaluation of the localisation algorithm on large networks. Results show that using our approach, an infrared network built with low-cost consumer grade components which lack explicit signal strength or bit error rate measurement capabilities, can accurately estimate the position of its member nodes.