Poster Abstract: Field Test of the Intelligent Container

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Wireless sensors networks for transport supervision

Quality losses during the transportation of food products can be avoided by accurate supervision of transport parameters, especially the temperature. The intelligent container measures local temperature deviations by a wireless sensor network. A gateway checks if the parameter or the quality thresholds are violated. The data are sent over an external communication network to a web-server, which provides access to the sensor data by a graphical user interface. The first field test under actual conditions of sea transportation of bananas from Central America to Europe was carried out in September 2009. Two fully loaded containers were equipped with 20 wireless sensor nodes each. Data were sent over wireless LAN to the captain's bridge. From there they were forwarded over a satellite link using the existing email system. The signal attenuation by the loaded bananas was extremely high. 50% of the transmitted packets were lost after a distance of only 0.5 meters between the sensor nodes.

The BananaHop protocol

A new sensor network protocol was developed. A simplified routing mechanism was used in order to reduce the amount of control messages, radio-up-time, and therefore, energy consumption.

In the first phase of the protocol the distance of the sensor node is estimated as the hop-level by forwarding a beacon from the base station. After receiving a beacon each sensor calculates the probability that it can send data to the base station over the inverse link as a function of the Received Signal Strength (RSSI).

During the data phase, all sensors are assigned to a certain time slot, depending on their hop-levels. This allows for low radio-up-times without increasing the risk for collisions. Communication is rather between the hop-levels than between the individual sensors. The sensors with the highest hop-level are enabled to send first. By this approach all sensor data are transmitted to the base station within one frame.

Measured RSSI and packet rates

The RSSI values of all received beacons from the neighbouring sensors were written to the flash memory of each sensor node in every fourth frame. An analysis of the flash records showed that most sensor data losses were caused by missing links, not by inadequate routing. The RSSI values for links with distances of 0.5 meters were typically between -75 dBm and -95 dBm, where the latter one is the receiving threshold of the TelosB nodes with the CC2420 radio chip. A quarter of the links failed completely or in more than 90% of all frames. For half of the links the packet rate changed over time with drops to zero for one or several days. The remaining quarter of the links provided almost stable data transfer over the full experiment duration.

Both protocols were compared with a theoretical reference protocol that finds all existing links from a sensor node to the base station. The percentage of sensor data that was successfully transferred to the base station was calculated by a simulation based on the RSSI flash records.

For most sensors both protocols achieved a similar rate in the field test as the reference protocol. Only for a quarter of the sensors the rate of the BananaHop protocol was between 10% and 20% lower than the reference rate. A further simulation showed that the rate of the BananaHop protocol can be improved by an automated adjustment of the internal RSSI thresholds.

The BananaHop protocol clearly required very low energy. All sensor data were transferred within one frame with an average radio-up-time of 7.5 seconds, whereas a more general protocol as the applied SensorScope protocol required two frames with a radio-up-time of 15 seconds to transfer one set of sensor data.

Conclusions

The tests showed that the remote monitoring of spatial temperature deviations is feasible. The BananaHop protocol provides an energy efficient routing mechanism. But the signal attenuation by water-containing products presented a serious problem for the wireless supervision of food transports. Either the number of sensors has to be increased or the sensors with a higher transmission power have to be used in order to provide stable communication. Alternatively, another lower frequency with a lower attenuation by dialectical losses can be used.

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