Noise Based Transmitted Reference Modulation for Wireless Sensor Networks

Mahdin Mahboob[1], Arjan Meijerink[1], Sarwar Morshed[2], Geert Heijenk[2], Mark Bentum[1]
University of Twente
[1]Telecommunication Engineering Group,
[2]Design and Analysis of Communication Systems Group,
P.O. Box 217, 7500 AE, Enschede, The Netherlands
Email: m.mahboob@utwente.nl

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Recent advances in the underlying technologies of wireless sensor networks (WSNs) have led to its use in different applications, from fields as diverse as battlefield applications to temperature control to healthcare. Research in the different aspects of WSNs is therefore in full swing, in both academia and the industry. In the Wireless Ad-hoc Links using robust Noise-based Ultra-wideband Transmission (WALNUT) project, modulation concepts (and relevant MAC protocols) are intended to be explored which allow for robust ad-hoc radio links with radio nodes implemented on a single CMOS chip. The WSN nodes (usually) work in an extremely crowded radio spectrum, thus making interference mitigation an important requirement, which is aimed to be done using noise-based spectral spreading.

Ultra-wideband communication systems are increasingly attracting attention because of their immunity to interference, robustness to multipath fading and ability to coexist with other devices in the same spectrum space. For such systems, a Rake receiver to collect all multipath components is a common design approach, but for WSN systems, such a system is not suitable because of its high complexity. Also, an accurate estimation of channel state information is required for such a system in order to adapt weight and delay of each Rake finger (which is prohibitive in case of low duty cycles). Both these constraints can be overcome by using transmitted-reference (TR) modulation, which allows for non-coherent (without channel state information) reception with lower energy usage.

In the TR scheme [1], a sequence of ultra-short pulses is used as the spreading signal and both a data-modulated and an unmodulated version of each pulse is sent towards the receiver. To distinguish between the modulated and unmodulated pulses, a time offset (delay) is introduced between the pulses prior to transmission. The original data signal is restored at the receiver by correlating the received signal with a delayed version of itself. An important criterion here is that the time offset at the transmitter and receiver must be equal for successful demodulation to take place. Because both the modulated and the unmodulated pulses travel through the same channel (and face the same channel impairments) each of the multipath components will contain two identically distorted pulses with consistent mutual delay (if signal is in coherence time of the channel). Hence, a Rake receiver or channel state information is not required for the demodulation. Also, a shorter time is required at the receiver for signal acquisition resulting in lower duty-cycle and hence lower power consumption. In this system, instead of pseudo-random UWB pulse sequences, random noise can be used, as shown in [2]. Instead of time offset, a frequency offset system may also be used [3],[4].

Other advantages in the proposed system include: **i)** Stable oscillators (which usually take up a large proportion of power in WSN radio) are not required for channel generation and selection circuitry. **ii)** Pure noise (as the information bearer) is relatively easy to generate. **iii)** Transmitters can transmit simultaneously by employing different time/frequency offsets. This means there is no requirement for mutual timing coordination. Hence, asynchronous operation is possible which offers additional flexibility at the MAC level.

Also worth mentioning here is the major disadvantage of a TR scheme, which includes the necessity to send the same message twice (both the modulated and unmodulated versions), the process consuming at least twice the power required compared to a non-TR system. But because energy is saved in a TR-scheme by shorter synchronization time, there is an overall power advantage compared to a non-TR scheme. The TR scheme is suitable for specific applications like short range bursty traffic in WSN which is being considered in this project.

Cross-disciplinary work is in progress in three related but distinct fields:
i) Physical Layer Aspects – Choice of suitable noise-like carriers which can be implemented at low cost and low bit error rate has to be made and suitable modulation techniques and channel codes have to be found. The receiver structure has to be designed, synchronization should be achieved, and the impact of channel and interference has to be studied. **ii)** Integrated Circuit Design – Sufficiently sensitive low-power radio receiver and radio circuits ($<100\mu W$) and high efficiency power transmitters have to be designed. **iii)** Communication Protocols – Medium access control for sensor networks with very short packets and inherent channel partitioning have to be established and protocols for extremely low duty-cycle network operation in a multi-hop environment have to be designed.

The project aims to achieve robust, low power communication between a transmitter and a set of receivers, not just theoretically, but also implemented in low-power ICs and combined with a relevant MAC layer protocol to make a complete communication system.

References:

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