Designing large-scale sensor networks (or large-scale distributed signal processing systems in general) is an extremely demanding task because complex balance should be maintained among many (frequently contradicting) requirements and constraints. The design process should be supported by a proper set of tools, which – using various models (e.g. functional, power consumption, failure, costs, etc.) – simulates the operation of the network and quantitatively characterizes the performance of the different design alternatives and thus help the designer to make the proper design choices. Many characteristics of the complete system are the result of the interactions among the different aspects of the design, e.g. the assignment of functionalities (program segments) to various processing units, the impact of communication topology on the execution of particular algorithms, etc.), Due to the large-scale of the system it is not feasible to execute the programs "instruction by instruction". Rather models of the programs should be used, which reflect the relevant features of the program but do not need instruction level execution.

The assignment investigates the different approaches for modeling (parallel) program execution and the interactions between parallel programs. A modeling proposal should be developed, which satisfies the needs of the quantitative evaluation of sensor network architectures. Simulator should be developed, which executes the application program models and measures the execution performance.

Title: Large-scale parallelization of dispersion models
Type of assignment: Internship/MSc Project
Contact: Zoltan Papp (zoltan.papp@tno.nl) or Joris Sijs (joris.sijs@tno.nl)
Description
One of the typical use of sensor networks is environmental (pollution, noise) monitoring. The collected observations are fed into simulation and prediction models to calculate the distribution and dispersion of the pollutants. With the advance of sensor networks a new class of "distributed computing platforms" became available consisting of very big number of relatively low performance connected nodes. Unfortunately due to power constraints the communication is limited in bandwidth and in space. Implementing the dispersion models on this type of platforms is a challenging task - but on the other hand the big number of nodes would enable robust (fault tolerant) operation and the usage of high-density measurements.

The assignment would overview the different dispersion modeling approaches with strong emphasis on parallelizable cell-based types. A few alternatives should be designed and evaluated for environmental pollution monitoring or micro-climate control. A feasible solution should be demonstrated on a small-scale WSN.

Title: Recognition of spatially distributed temporal event sequences in sensor networks
Type of assignment: Internship/MSc Project
Contact: Zoltan Papp (zoltan.papp@tno.nl) or Joris Sijs (joris.sijs@tno.nl)
Description
Wireless sensor networks are frequently used to monitor spatially distributed dynamical systems (e.g. traffic, living environments, etc.). A subset of these monitoring problems relates to understanding the underlying process based on discrete events associated with significant changes in the process observed (e.g. a gate has been opened indicating somebody is entering a territory, periodic changes in the cruising speed on a highway segment indicating the emergence of "shock waves, etc.). Particular event patterns (both spatial and temporal dimensions) indicate "interesting"
situations, which should be recognized and possibly intervening action should be executed. On the other hand the sensor nodes have limited sensing ranges (defining the "area of interest") and thus spatial patterns can only be recognized via interactions among the sensor nodes.

The assignment addresses the modeling of discrete event systems and derives distributed algorithms, which recognize and classify spatio-temporal event sequences. The algorithm developed should be efficiently implementable on wireless sensor networks (e.g. power and communication constraints should be considered).

**Title: Experimental platform for environmental monitoring**
**Type of assignment:** Internship/MSc Project
**Contact:** Zoltan Papp (zoltan.papp@tno.nl) or Julio Oliveira de Filho (julio.deoliveirafilho@tno.nl)

**Description**
A number of experiments are planned in the environmental monitoring and precision agriculture domains to be carried out by professionals not having substantial WSN expertise. In order to support these experiments a wireless sensor platform is necessary, which supports component based application building (e.g. plugging in different protocols, routing algorithms, processing modules, etc.) and can be programmed using a (domain specific) high-level programming (scripting) language.

The assignment should evaluate existing runtime environments for WSNs concerning the requirements of the experiments planned and should design and implement a higher level a dedicated supporting ("middleware") layer on TinyOS. A prototype of software environment for assisting the programming of the experiments should also be implemented.

**Title: Distributed optimization**
**Type of assignment:** Internship/MSc Project
**Contact:** Zoltan Papp (zoltan.papp@tno.nl) or Julio Oliveira de Filho (julio.deoliveirafilho@tno.nl)

**Description**
Optimization of the operation of dynamical systems is a well developed area of research with great practical significance (e.g. joint optimization of traffic lights, power network maintenance, control of renewable energy sources, etc.). In spatially distributed cases (e.g. the examples mentioned before) the observations from the process cannot be communicated with a central place and thus optimization can only be done locally. The question is how the local optimizers should interact in order to achieve system level optimum. The problem is especially interesting in wireless sensor networks, where the number of nodes is high and the communication/power constraints are serious.

The assignment should overview the different types of distributed optimization problems and develop solutions for particular large-scale mobility related optimization cases (typical cases: traffic light management, cooperative highway on-ramp control).

**Title: Runtime reconfiguration in wireless sensor networks**
**Type of assignment:** Internship/MSc Project
**Contact:** Zoltan Papp (zoltan.papp@tno.nl) or Julio Oliveira de Filho (julio.deoliveirafilho@tno.nl)

**Description**
Wireless sensor networks consist of high number of nodes connected via uncertain communication channels and many times operate in hostile environments. During the life cycle of the system new components are introduced, the embedding environment can change significantly, etc. Consequently structural changes and failures are not exceptions but can be considered as "normal" operational pattern. The sensor network hosting (a part of) the signal processing functionalities
should be able to adapt its operation to these changes and thus assure the delivery of the services assigned. The design and development of programs capable of structural adaption in runtime pose significant challenges and the developer should be supported by dedicated development platforms and tools.

The assignment is to design and implement a middleware layer on the top of TinyOS, which gives significant functional support for implementing adaptive applications. The emphases should be put on the system level monitoring of relevant states and cooperative reasoning about the actions to be taken. (The work is a continuation of an MSc thesis work, which focused on monitoring and reconfiguration on node level.)

**Title: Programming models for large scale distributed signal processing systems (wireless sensor networks)**

**Type of assignment:** Internship/MSc Project

**Contact:** Zoltan Papp (zoltan.papp@tno.nl) or Julio Oliveira de Filho (julio.deoliveirafilho@tno.nl)

**Description**

In order to improve robustness, throughput, responsiveness and reduce power demand (wireless) sensor networks more and more host processing functionalities (in contrast with the "old school" approach, where the network embedded processing was hardly more than simple local filtering, compressing and routing the data to the sink node (which implemented majority of the processing)). These systems may consist of extreme number of nodes and the failures are not exceptions but occur in normal operation. The programming of applications on this hardware platform cannot be carried out effectively relying on the programming paradigms nominally used for embedded systems development.

The assignment overviews the state of the art of programming large-scale, robust, real-time distributed systems focusing on the conceptually different approaches (e.g. functional programming (e.g. Erlang), global-to-local compilation, etc.) and proposes a programming framework dedicated to large-scale wireless sensor networks. The framework should be demonstrated via a pilot application, e.g. spatial pattern recognition with wireless sensor networks.

**Title: Gossiping based signal processing**

**Type of assignment:** Internship/MSc Project

**Contact:** Zoltan Papp (zoltan.papp@tno.nl) or Joris Sijs (joris.sijs@tno.nl)

**Description**

Gossiping is a novel approach to signal processing, which is especially suited for implementing in-network processing - and thus especially interesting for wireless sensor network based applications. Gossip algorithms do not require any specialized routing, they are fault tolerant and , and they are robust to unreliable wireless network conditions. This is an intensive research domain and more and more robust and efficient algorithms become available for signal processing and control.

The assignment is to design and implement a "gossiping toolbox", which helps developing and evaluating gossiping based signal processing algorithms. The relevant models for the embedding environment (e.g. communication channels, power demand, temporal properties, etc.) should be taken into consideration in order to make the evaluation realistic. The toolbox should be generic and extendable to incorporate new processing algorithms and environment models. A demonstrator should be implemented focusing on state and parameter estimation and tracking algorithms as example.

**Title: Cooperative monitoring using quad-rotors**

**Type of assignment:** Internship/MSc Project
Contact: Zoltan Papp (zoltan.papp@tno.nl) or Joris Sijs (joris.sijs@tno.nl)

Description
Quad-rotors are agile flying platforms, which can carry limited payloads and can be operated both indoor and outdoor. Consequently they are especially suitable for carrying out particular types of survey and monitoring tasks. Due to their inherent limitations they should rely on cooperation in order to complete the assigned tasks effectively (e.g. discovery of a building, finding objects, measuring spatially distributed system properties, etc.).

The assignment focuses developing and implementing robust, distributed planning algorithms and their real-time execution environment for map building object tracking. One of the main challenges of the design is to take into consideration the constraints of the platform (limited processing power, limited and unreliable communication, flight dynamics, limited power supply, etc.). The solution should be demonstrated in a small scale quad-rotor configuration. (The underlying functionalities (e.g. motion control, formation flying, localization, etc.) are available from previous MSc works. This assignment should address the higher level (coordination, planning, management) functionalities.)

Title: New computational basis for distributed algorithms
Type of assignment: Internship/MSc Project
Contact: Arvid Halma (arvid.halma@tno.nl) or Zoltan Papp (zoltan.papp@tno.nl)

Description
Interest grows in applications that are implemented on geographically distributed hardware, for example wireless sensor networks. Applications include pollution monitoring, traffic control and inspection of industrial plants. Typical challenges in implementing such networks are that communication is unreliable and expensive and that hardware configurations can change. A plethora of strategies are known in order to make reliable solutions.

This project will focus on designing a concise set of functionalities that can form a basis of techniques for common underlying problems, such as resource management, self monitoring. With the new toolkit, we hope to
1) express classical algorithms in a common way to gain deeper understanding among different implementations.
2) proof correct behavior more easily.
3) to develop new distributed algorithms more quickly.

As source of inspiration one can look at recent trends in functional programming and derived products such as MapReduce from Google. This project has a strong theoretical component, but it is desired that a reference implementation is developed in an programming environment of your liking.

Title: Mixed reality environment for wireless sensor network development and testing
Type of assignment: Internship/MSc Project
Contact: Zoltan Papp (zoltan.papp@tno.nl) or Julio Oliveira de Filho (julio.deoliveirafilho@tno.nl)

Description
Sensor networks may easily scale to systems with hundreds of interacting devices spread over an outdoor large area – this is the typical case, for example, when monitoring pollution, noise, or the traffic along a highway. The development of such large-scale systems in laboratory and their implementation in the field are still unmatched tasks because the environment frequently affects sensors and communicating parts in an unforeseen way. For example, temperature variations, electric noise, humidity, or vandalism can modify the properties of sensors, introduce communication problems, and make part of the system unusable. The
development/implementation of sensor networks can be made more robust and reliable, if part of these effects can be artificially reproduced, emulated, and tested in laboratory.

The assignment targets a development tool, which is able to generate and "inject" virtual sensor readings (based on various dynamical system and sensor models) into the sensor network and thus can bring it into various operational conditions. Some readings may come from real sensors (eventually from remote locations via internet) thus the sensor (processing) network is placed into a mixed reality environment. The goal is to develop an extendible, open tool, which can easily incorporate wide variety of environmental model and data feeds. The tool should be integrated with an existing wireless sensor network development environment (installed at TNO).