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Automated Protocol Selection for Energy Efficient WSN Applications

C. Shen, S. Harte, E. Popovici, B. O'Flynn, R. Atkinson and A. Ruzzelli

A mature wireless sensor network automation tool requires the implementation of different protocols for different topology & application scenarios to optimise the overall system performance. Focusing on the transport layer energy-aware routing function for the Tyndall Heterogeneous Automated Wireless Sensor (THAWS), we propose to embed a reactive routing protocol, an energy-efficient proactive heuristic protocol and a distributed geographical routing mechanism on the Tyndall 10mm and 25mm nodes. Those protocols manage small, medium and large sensor applications adaptively, while the end users of the THAWS tool are transparent from protocol selection.

Introduction: The Tyndall Heterogeneous Automated Wireless Sensors (THAWS) tool has two types of nodes with different node layers developed by Tyndall Nation Institute [1]. Two modular nodes have been designed with a size of 10 mm by 10 mm, and 25 mm by 25 mm. These are referred to as the 10mm and 25mm nodes shown in Fig. 1. Sensor layers can then be connected with application specific sensors. In addition to sensors, a battery or energy harvesting device can be connected to provide a power supply and each node can also provide its own energy level reading. The 25mm node has an Atmel ATmega128 microcontroller with 128 kB of program memory. It owns a layer using a Nordic nRF2401 transceiver and another layer using an Ember EM2420 ZigBee 802.15.4 compatible transceiver. There is also a 433/868/915 MHz layer using a Nordic nRF905 transceiver, which allows a longer range. The 10mm node is currently a single transceiver layer, which uses a Nordic nRF905 chip. The chip has a radio that is compatible with the Nordic nRF905 so this allows heterogeneous networks to be built.

The core of the THAWS is an application generating tool, which has two main parts. The first part is a software library containing modules of code that act as primitives in building up sensor applications and the second part is a description of the desired application. The second step of developing the THAWS tool is to realise energy-aware functions focusing on dynamic routing as the key enabler. Instead of using only one specific protocol, we propose to take advantage of multiple protocols according to real-time system conditions and adaptively adjust the routing protocol based on real-time monitoring. Therefore, this letter discusses a novel concept: The automated protocol selection for energy constrained Wireless Sensor Networks (WSN).

Automated protocol selection: As fast deployment requires the inter-interoperability between different components and interfaces, we first draw a simplified schematic for the automated network routing in Fig. 2 to introduce main components and input & output interfaces. Three categories of components are used for real-time sensor data monitoring, which are network topology, network representatives and application representatives. The network topology component monitors the changes of sensor node position and sensor network topology when mobility is introduced to sensor nodes.

The network representative periodically extracts the data to monitor max delay of packets, network throughput and mostly importantly, network energy efficiency. The application representatives also periodically monitor the feedback data from an application regarding the data of updated application throughput and stability.

The three components together provide the network input, while the input is translated into data context to be processed by the THAWS tool. The tool is located at a sensor network gateway as such a design can provide Ipv6 over Low Power wireless personal networks (6LowPan) based THAWS remote control, virtual control and more importantly, both 25mm and 10mm nodes save energy on data exchange overhead. The gateway decides the best routing protocol and delivery the routing decision to nodes for different scenarios e.g. city carbon foot print monitoring or assisted living system. Three candidates routing protocols pre-stored in nodes memory are: 1. Geographical Routing (GR) [4], 2. Proactive heuristic algorithm based Routing with cost function (PR) and 3. Reactive modified ad hoc on demand Routing (RR). The PR is ideal for small and medium network topologies. A heuristic cost function can be used for further protocol optimisation or to emphasise the energy-aware objective:

$$F = \alpha E + \beta D + \gamma A$$

Each parameter has been given a weight factor where α for energy consumption of nodes function E, β for packet delivery function D and γ for application data function A. The sum of $\alpha + \beta + \gamma = 1$ and we can assign a bigger value to α save node energy when finding next hop node. The RR is suitable for large and dynamic network topologies, NST-AODV [2] is used to decrease data latency, increase system reliability and save power and memory storage cost. The GR applies on any network topologies with low mobility for efficient distributed data fusion application. The protocol only requires each node to keep state only about its neighbours and does not require geographic location information due to the 6lowPan implementation with a permanent IPv6 physical address.

As shown in Fig. 3, the THAWS automated routing operates from the system input to the system output. The system initialisation block gathers information including network topology, user requirements, packet dissemination method, delay constrains, data format, etc to feed the embedded OMNET++ [3] simulator. After the simulation verification which lasts a few seconds, the results are automatically generated through context block while the THAWS tool at a gateway makes the first routing protocol selection decision. The routing delivery continues with the operation flow. The THAWS tool then periodically collects real-time system output after the validation from the data feedback block. The application transporting method may migrate from one routing protocol to another based on the THAWS decision. The real-time online monitoring loop only ends when enough tasks have been finished or due to system failure.

Discussion: The automated protocol selection method is the first to introduce protocol usage flexibility and self-configuration to an embeded sensor network. This real time framework, before implementation, will be intensively tested and compared to other fixed protocol based systems to optimise the system performance.

Conclusion: In this letter, we propose a novel THAWS based automated routing selection method to fully utilise the system resource and save sensor system energy. The originality of the work is that the framework fully integrate the sensor network with 6LowPan, the protocol stack and the automated real-time feedback control and simulation based validation function. Self-management is achieved to overcome the rapidly growing sensor application complexity and to reduce the cost for operations.

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Figure captions:

Fig. 1 10mm (left) and 25mm (right) modular Tyndall nodes.

Fig. 2 Automated network routing components & interfaces schematic.

Fig. 3 THAWS automated routing operation flow

Figure 1

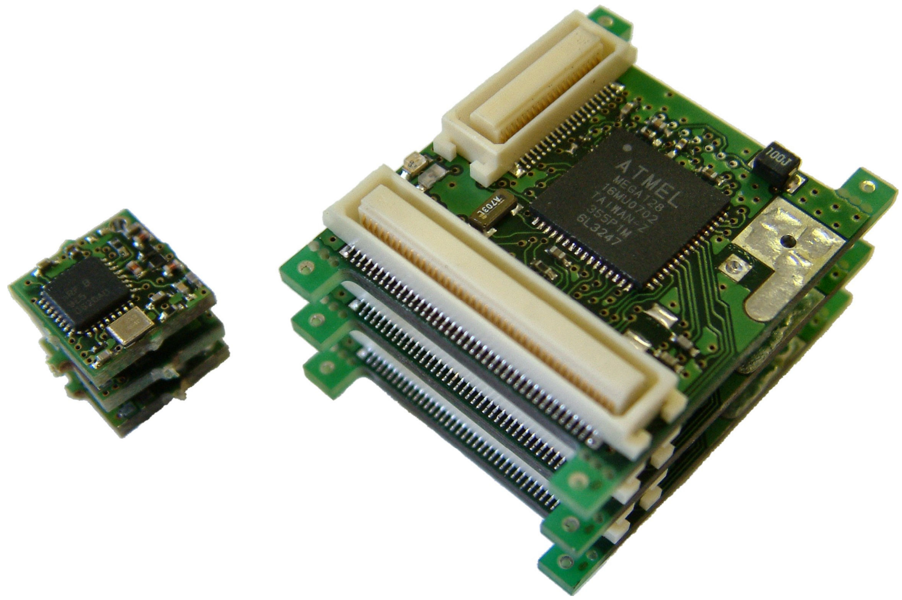


Figure 2

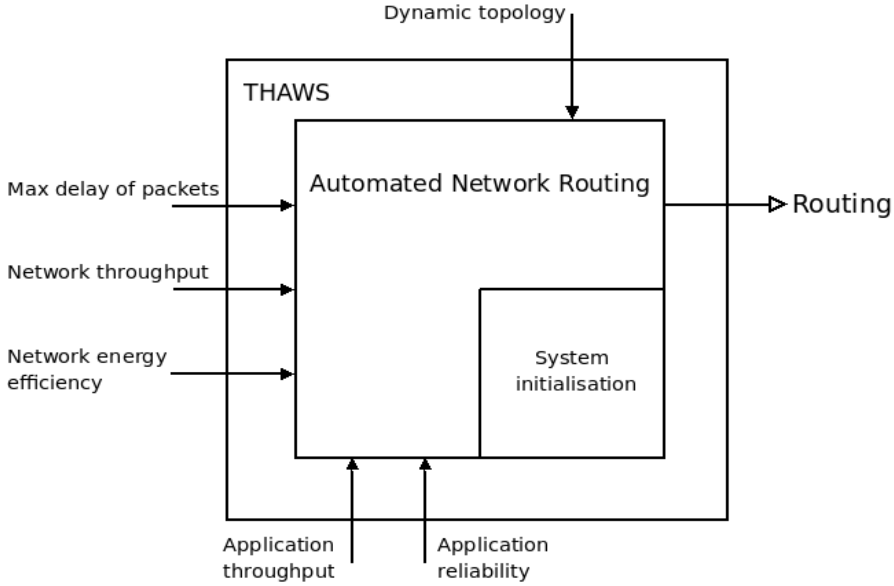
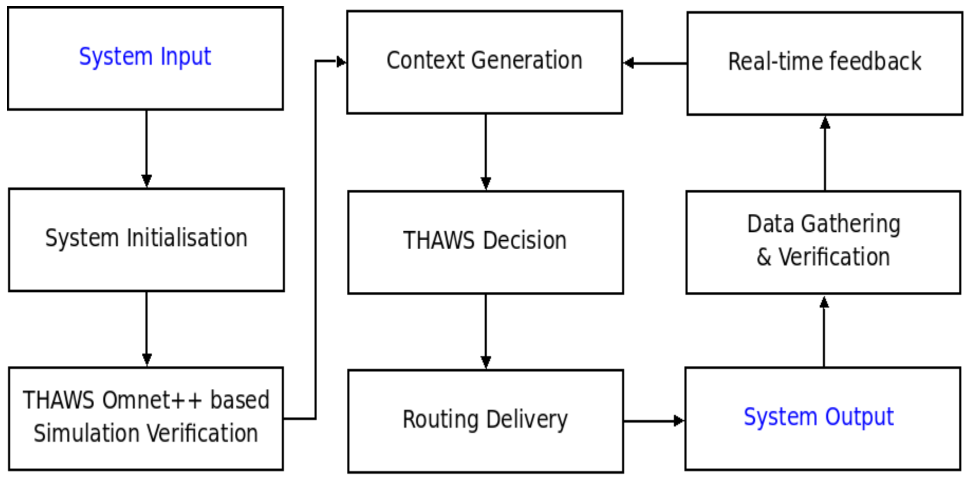

Dynamic topology
THAWS
Automated Network Routing
Max delay of packets
Network throughput
Network energy efficiency
Routing
System initialisation
Application throughput
Application reliability

Figure 3


System Input
System Initialisation
THAWS Omnet++ based
Simulation Verification
Context Generation
THAWS Decision
Routing Delivery
Real-time feedback
Data Gathering
& Verification
System Output