Demo Abstract: GinLITE - A MAC Protocol for Real-Time Sensor Networks

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***Abstract*—In this demo we present the GinLITE medium access control protocol. GinLITE is a generic open source medium access control protocol designed to offer time-critical and reliable data delivery. GinLITE is easily extensible and customisable and is intended to be used as a building block for research sensor networks that have strict performance requirements. The protocol was developed as a component for the GINSENG system, a system designed for industrial process automation and control applications. A simple application is presented for the purpose of demonstrating the capabilities of GinLITE.**

I. Introduction

The majority of manufacturing industries utilize systems to monitor and control their production processes. For instance, in a typical oil refinery, such systems are usually made up of a distributed network of various in-field devices monitoring and controlling pumps, valves, motors etc. These process control and automation applications can be considered as real-time. Automated control loops are mapped onto a wireless network and it is essential for their correct functioning that messages are delivered timely and reliable. Whilst traditionally fixed wired networks have been used for such scenarios, the use of wireless sensor networks is compelling due to increased flexibility and reduced economical cost. However, WSN's have conventionally been relatively unreliable, with little to no consideration for real-time behaviour, making them unsuitable for the outlined scenario.

Recently a number of systems have materialized that have been designed to offer real-time and reliable data delivery to support such time-critical applications. These systems generally use at their core parts of the IEEE 802.15.4 standard and a time division multiple access (TDMA) protocol. The TDMA MAC schedule is provisioned to support the requirements of the application with adequate spare capacity to increase reliability. Such systems have been commercial in nature and typically span across different entities outside of the WSN for instance management systems. The need for other external entities to the WSN and their closed commercial nature, blocks the use by the research community of these systems making research in this area challenging. Examples of such systems are WirelessHART and ISA100.11a.

The EU-funded GINSENG project was set up to investigate the problems associated with supporting industrial process and control applications through wireless sensor networks. The designed GINSENG system [1] is a research platform built to support time-critical applications. The system provides novel software components such as real-time OS extension, real-time communication protocol, topology and traffic management and deployment and debugging facilities.

The GINSENG system assumes a carefully planned deployment of static sensor and actuator nodes as the basis to achieve performance control. The heart of the GINSENG system is the TDMA MAC protocol GinMAC [2]. It uses a virtual tree topology alongside a pre-computed exclusive TDMA schedule, optimized to the requirements of the application. Reliability is ensured by the provisioning of redundant slots within the schedule for retransmission whose number is determined during pre-deployment measurements. GinMAC provides attachment points for other GINSENG system components such as topology control, traffic management or performance debugging. The GINSENG system has seen extensive testing in a number of lab based experiments in addition to a long term deployment on a testbed in the Sines Oil Refinery in Portugal. The different components and capabilities of the overall GINSENG system are described in [3], [2], [4], [5].

In addition to industrial process control, many other domains also require reliable time-critical data delivery. With the lack of available open source off-the-shelf systems to support these requirements, commencing research in these areas is difficult. Whilst the GINSENG system could be used to support such research, it would often be considered excessive and to complex providing many unnecessary features which have been tailored to particular industry settings. Instead a reduced system is needed designed as a research enabler for real-time wireless sensor networks. This reduced system is GinLITE, a derivate of the original GinMAC, designed to provide only the essential minimum features and to support modification to adapt the protocol to a variety of real-time research tasks.

In this paper we describe core features of GinLITE and the demo showcases its capabilities.

II. GinLite Overview

GinLITE is implemented for the Contiki sensor network operating system. GinLITE supports a number of advantages and improvements over GinMAC such as reduced resource use, a simpler implementation, better integration into ContikiOS

and increased stability. These features make the system more suitable as a reliable research platform.

The system requires less than 5KB of flash memory which is comparable to other Contiki MAC protocols that do not have to deal with the complexity of supporting real-time communication. With regards to RAM the system requires 1.2KB of RAM which includes support for a frame queue of 8 frames. This queue partially replaces the default queue of 16 packets held in the Contiki RIME system. With a modest Rime based application, only 23KB of flash and 3KB of RAM are used leaving 25KB of flash and 7KB of RAM available on a commonly used Telosb mote for system extension.

The implementation of GinLITE has a simple structure with the entire MAC protocol contained in a single file in a similar structure to other Contiki MAC protocols.

Additional components such as Topology Control, Overload Control or Performance Debugging can be attached. However, the basic system only includes minimal implementations of these add-ons. For example, the system utilizes a purely static topology with pre-computed and static TDMA schedule. However, if a research project requires, a complex topology management component can be added. The system provides mechanisms to transmit additional information piggybacked on data transmissions which allows researchers to construct complex performance monitoring components without disturbing real-time communication. The basic system supports a simple FIFO queue but this can be replaced by sophisticated queue management if the targeted research requires this.

GinLITE has been designed to be tightly integrated with ContikiOS, implementing the standard Contiki MAC interfaces. This allows the system to be used in the same way as other built-in MAC protocols. This allows the system to be used with ease, with the provided ContikiOS example RIME based applications and with some small modifications with 6lowpan applications.

The GinLITE system is currently compatible with ContikiOS 2.4 and can be downloaded from [1].

A. Using GinLITE

GinLITE is a TDMA mesh-under MAC protocol and as such it requires topology and TDMA schedule information for operation. If no complex topology management is implemented, static topology/schedule information can be supplied via configuration files. Examples for this configuration procedure are supplied with the available code.

For a simple static topology, the number of nodes at each layer of a tree beginning with the sink needs to be specified. Furthermore, each nodes position in the tree must be configured.

Each node adheres to a configured schedule. This schedule consists of active slots used for transmission and reception of data and inactive slots that are used for application processing or to conserve energy. Transmission slots are used exclusively to avoid collisions. Slots are allocated to nodes for transmitting their own data and for forwarding data from/to nodes located further down in the tree topology. Redundant slots can be specified which will be used for retransmissions if needed. By specifying the right number of redundant slots, reliability targets can be met.

The application can use the Contiki Rime stack with GinLITE in the same way as other protocols. Packets can be created and passed to the send function and received via a callback function. To ensure real-time processing, the MAC protocol utilises a Contiki rtimer executed function operating outside of the run-to-completion environment. As the callback receive function will be invoked from this rtimer function, to maintain real-time performance it should be minimal and simply store the packet for later processing by its thread.

B. The GinLITE Demonstration

To demonstrate the GinLITE capabilities a tree topology consisting of 11 nodes is used. The schedule length is set to be one second which ensures that all data arrives at the sink within one second. The application uses the Rime stack and each node reports temperature reading and button state to the sink node connected to a pc. The pc will display received data and, for demonstration purpose, additional performance metrics such as message delay and reliability. A button press will generate an actuator message that will be sent from the sink to a specific node to enable a led.

III. Summary and Future Work

This paper has presented GinLITE an open source MAC protocol built to provide reliable time-critical data delivery. It is our plan to continue the development of the GinLITE system providing bug fixes and optimizations as well as porting GinLITE to future versions of Contiki including the recently released Contiki 2.5 in addition to other hardware platforms such as the Zolertia Z1 mote.

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