MIRTES: Middleware for Real-time Transactions in Embedded Systems

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Summary

MIRTES is a long term project aiming to develop a middleware for Wireless Sensor Network (WSN) having real-time features and offering data-, event-, and code-centric services. A first release of MIRTES, offering data-centric services with real-time support, has already been implemented and will be used in the IPERMOB project.

Motivations

Current middleware packages lack support for real-time transactions, thus they are not effective for real-time applications such as process control, industrial automation, etc. Moreover, they are often constrained to only one type of service (data-, code-, or event-centric), whereas a complex application may require to combine all of them.

Implementation

- Based on the ERIKA real-time micro-kernel and µWireless (its IEEE 802.15.4-compliant stack)
- Running on Microchip dsPIC33 and PIC32 microcontroller based boards.

Experimental validation

- t=0: two periodic queries are spawned
- t=5: a burst of snapshot queries is spawned

The lateness of the two periodic queries (black and red dots) is always negative proving the real-time effectiveness of MIRTES scheduler

The intelligent transportation system domain

- IPERMOB: A Pervasive and Heterogeneous Infrastructure to control Urban Mobility in Real-Time
- IPERMOB proposes low-cost wireless technology (WSN) and image processing techniques to estimate traffic-related information.

The Pisa airport landside will be the test-bed of the project

Ongoing work

- Multi-hop communication
  - Extension of the communication strategy to a cluster tree topology
  - Network layer compliant with 6LoWPAN specifications
- Event-centric services
  - Instantiation of an event registry
  - Implementation of an event notification policy
- Code-centric services
  - Integration in MIRTES of the already-available support for firmware remote reprogramming

Background

A middleware for WSN is a software infrastructure that, gluing together hardware drivers, operating systems, network stacks, and application services, hides the complexity of the WSN simplifying the application development. A data-centric middleware eases the access to the sensor readings usually abstracting the WSN as a database. An event-centric middleware allows the WSN to detect a set of events specified by the user. A code-centric middleware manages the firmware of the sensor nodes allowing to change their behavior on-line.

An application is said to be real-time when its correctness depends not only on the logical result of the computation, but also on the result release time. In real-time systems (at variance from other systems) deadlines and other explicit time constraints are usually attached to tasks in the form of descriptors.

Current features

The current release of MIRTES offers data-centric features by abstracting the WSN as a database. The user can query the virtual database using SQL. MIRTES supports SELECT queries with:
- WHERE conditions;
- Aggregation functions;
- HAVING conditions.

In terms of real-time, MIRTES supports two types of queries:
- periodic query with real-time guarantees (periodicity and deadline);
- snapshot query without real-time guarantees (but served without interfering with periodic query timeliness).

Communication strategy

MIRTES communication strategy exploits the IEEE 802.15.4 standard which supports real-time traffic by means of the Guaranteed Time Slot (GTS) mechanism (dynamic TDMA). Currently it uses a star topology in which the Network Access Point (NAP) is the network coordinator allocating bandwidth to the sensors.

The bandwidth is scheduled by the NAP using the Earliest Deadline First (EDF) policy with admission control for periodic queries and with a Total Bandwidth Server (TBS) serving snapshot queries.

The NAP sends the query in the beacon payload and allocates a GTS to each sensor involved in the query.