Modelization of Temporal Mechanisms for Sensors Networks

P. Lorenz[1], M. Gilg[1] and J. J. P. C. Rodrigues[2]

[1] University of Haute Alsace
34 rue du Grillenbreit 68008 Colmar- France

[2] Instituto de Telecomunicações, University of Beira Interior
Rua Marquês D'Ávila e Bolama
6201-001 Covilhã, Portugal

pascal.lorenz@uha.fr, marc.gilg@uha.fr, joeljr@ieee.org

Abstract. This paper presents technical specification to define temporal constraints for communication networks. Temporal statuses are generated to test the temporal validity of the exchanged data. Simulations are done to prove the validity of our model for sensors' communications.

Keywords: temporal systems, sensors networks, real-time systems, modeling

1 Introduction

For some applications using sensors networks, it is necessary to respect real-time constraints [4], [7], [15]. For example, in a car using sensors networks, the communication between the sensors connected to the brake and the actuators connected to the wheel should respect real-time constraints (such as millisecond or nanosecond). The non-respect of real-time constraints introduces danger for peoples and for materials. Today very few networks offer real-time or time-critical mechanisms.

Therefore new temporal mechanisms should be used to enable to respect real-time constraints in networks sensors [5], [10], [14].

The rest of this paper is organized as follows. Section2 describe the different temporal mechanisms with the introduction of the Temporal Window (TW) and of the Variable validity time Window (VW). It develops a modeling approach of the temporal mechanisms. Simulation of the temporal mechanisms applied to sensor networks is conducted in section 3. Section 4 concludes this paper and points further research directions.

2. Temporal mechanisms

Temporal mechanisms are very important to provide quality-of-service (QoS) mechanisms for real-time applications [6], [8]. The temporal interval used for a communication can be divided into several sub-temporal intervals to enable the localization of an error and to know if the global temporal communication has not been respected.

The three major steps are the following:

- *i*) production of the information by the sensor;
- *ii*) propagation of the information through the medium
- *iii*) the consumption of the information by the actuator [2], [13].

At each step of the communication, temporal statuses should enable to know if the temporal constraints have been satisfied.

The production, the transmission and the consumption temporal statuses (noted respectively to PS, TS, and CS) are used to know if the temporal at the different steps have been respected or not. In this work, we will suppose that local clocks of production and consumption entities are synchronized. If this hypothesis is not respected, it is not possible to manipulate temporal constraints because the fact that a data production date is superior to the consumption date for the same data is not possible [3], [9], [11], [12].

We will use the notion of Temporal Window (**TW**), in which information should be managed at a given time, not too early (not before the beginning of the temporal window) and not too late (not after the end of the temporal window), but just in time.

The three activity temporal windows are the following:

- production of the temporal window (noted to prod);
- transmission of the temporal window (noted to trans);
- consumption of the temporal window (noted to cons).

i and *v* parameters are used to represent the i^{th} temporal window used for a given variable *v*. Then, a time window can be described as follows:

State Function TW (v, i) with
State = (**S**tart, **E**nd or **D**uration) and
Function = (production, transmission or consumption)

Some rules can be elaborated, for example the fact that the start of a TW appears always before the end of the same TW. This rule can be described as follows:

Start Function (*v*, *i*) < End Function (*v*, *i*) (1)

At a given time, a produced data has duration of life which can changes according to consumers entities.

For statistical application, data validity can be unlimited but not for time critical applications. So data validity depends on the utilization of this later. For example, the validity of a temperature can be considered as valid (as long as a new updated data has not been produced) even after the end of the temporal window.

To formalize the concept of data validity (duration of life), the term of Variable validity time Window (noted **VW**) will be used. A temporal window for data validity is described as follows:

State VW (*v*, *i*) with
State = (**S**tart, **E**nd or **D**uration)

3. Modeling of temporal mechanisms

At a given time, it is important to know if the current state is located inside or outside a TW and a VW ; and to know if the state VW(v, i-1) exists or not.

The different possible situations for a TW and a VW are:

1) located out of a TW, out of a VW and it does not exist a VW for a given variable v; this state is called *False* state,

2) located in a TW, out of a VW and it does not exist a VW for a variable v; this state is called *Wait* state,

3) located in a TW and in a VW; this state is called *True* state.

4) located in a TW, out of a VW and it exists a VW for a variable v; this state is called *VW-Expiration* state,

5) located out of a TW and in a VW, this state is called *TW-Expiration* state,

6) located out of a TW, out of a VW and it exists a VW for a variable v; this state is called *TW+VW-Expiration* state.

The six different possible situations described below are represented in the figure 1.

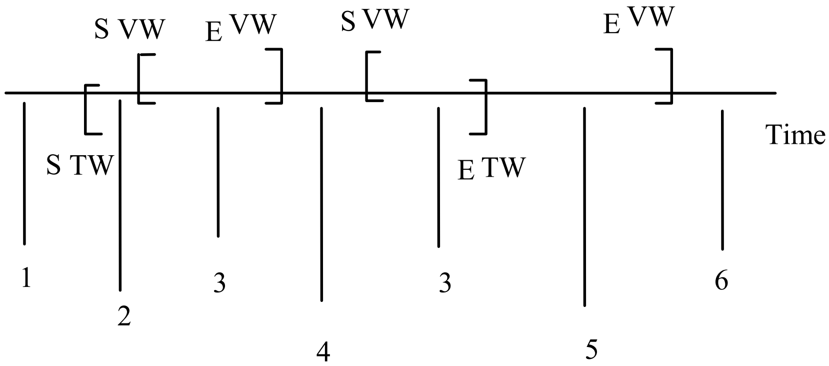

Fig. 1: Relationships between Temporal Window and
Variable validity time Window.

Then the six possible combinations between the TW and VW are:

- 1 = *False state*: located out of a [Start Function (v, i), End Function (v, i)], out of a [Start VW (v, i), End VW (v, i)] and it does not exist a Start VW (v, i-1)

- 2 = *Wait state*: inside the a [Start Function (v, i), End Function (v, i)], out of the [Start VW (v, i), End VW (v, i)] and it does not exist a Start VW (v, i-1)

- 3 = *True state*: inside the [Start Function (v, i), End Function (v, i)], inside the [Start VW (v, i), End VW (v, i)], then at least one variable v has been produced respecting the timing constraints

- 4 = VW-Expiration state (noted *Expiration1* in the figure 2): inside a [Start Function (v, i), End Function (v, i)], out of a [Start VW (v, i), End VW (v, i)] and it exists a Start VW (v, i-1)

- 5 = TW-Expiration state (noted *Expiration1* in the figure 2): out of a [Start Function (v, i), End Function (v, i)], but inside [Start VW (v, i), End VW (v, i)]

- 6 = TW+VW-Expiration state (noted *Expiration2* in the figure 2): out of the [Start Function (v, i), End Function (v, i)], out of the a [Start VW (v, i), End VW (v, i)] and it exists a Start VW (v, i-1).

In the industry there is a lot of real time communication requirements (for example for networks in a factory, in a car, in a airplane, etc …). The non-respect of the time constraints can cause the dead of peoples and/or the destruction of materials [1].

To simulate the temporal communication between sensors, we will add to each step of the sensors' communications a time-out and a temporal status.

Therefore, a sensor can have three different statuses:

- data production in time (true or false),
- data transmission in time (true or false),
- data consumption in time (true or false).

For each communication step, we will have a start event (generating an event to start the TW and the VW) and an end event (generating a time-out to close the TW and the VW).

The protocol integrating the 6 different states of the TW and VW is described in the Figure 2.

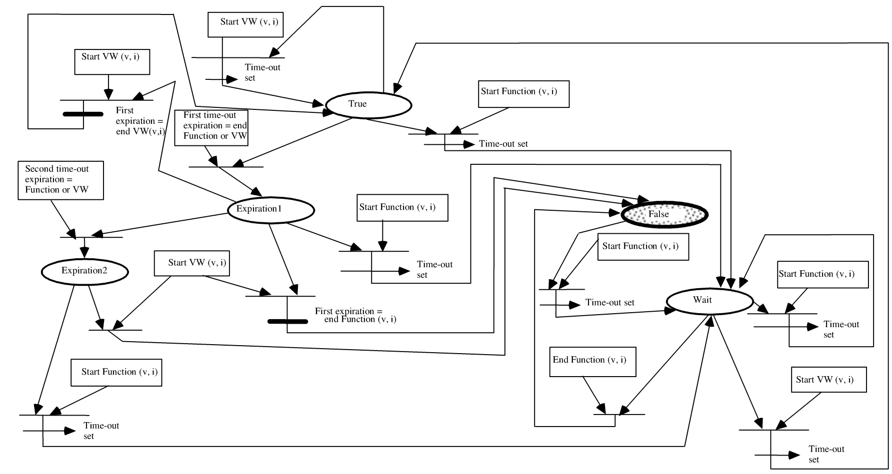

Fig. 2: Description of the proposed protocol integrating Temporal Window and Variable validity time Window.

4. Simulations applied to sensors networks

The simulations are done with OMNET++ and MiXiM package. Three mobile nodes are broadcasting packets with a burst size of 300 packets. The nodes are moving constantly. For each packet we compute the delay between the packet creation and the packet reception. The packet is valid if the reception is done before a given deadline, defining the VW.

The TW is defined by two parameters:

- the Duration of the window DTW and
- the Start Time-Window STW.

A packet is valid if it is received at the given time Tr such as:

$$i * STW + (i-1) * DWT \leq Tr$$

and

$Tr \leq i * STW + i * DTW$ for a given integer *i*.

The simulation is done with STW=1 ms, DTW=2 ms and VW-Duration=40 ms. We will explain the behavior of packet received by the node 0.

Figure 3 shows the number of VW packets received in a simulation time slot. Each slot in the graph corresponds to a received packet. The different color in the graph corresponds to a different node. We can notice that this number is increasing until a WV-Duration of 45 ms because after this time the packets are buffered and are noted as received in a VW.

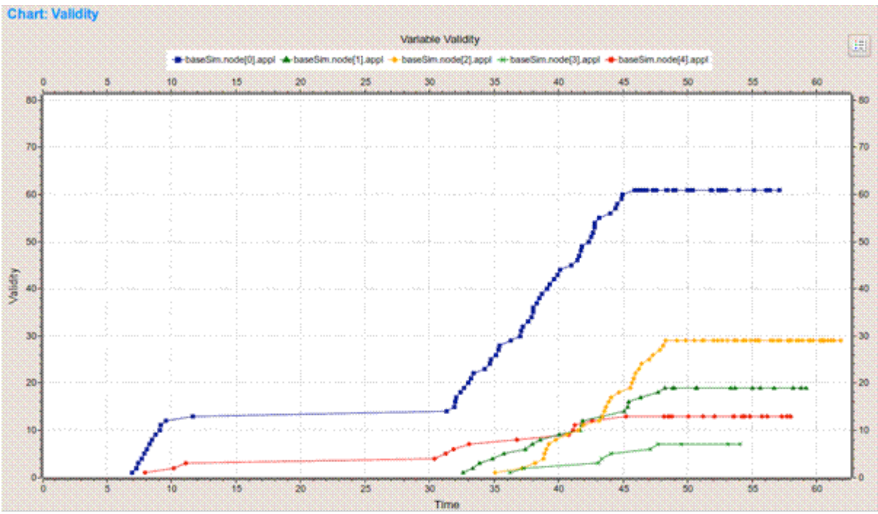

Fig. 3: Packets measured for Validity Time Window.

Figure 4 shows the number of packets received in a valid TW. We can notice that most of the packets are received in a valid TW. When the line is horizontal, this means that the packet is received outside of the TW.

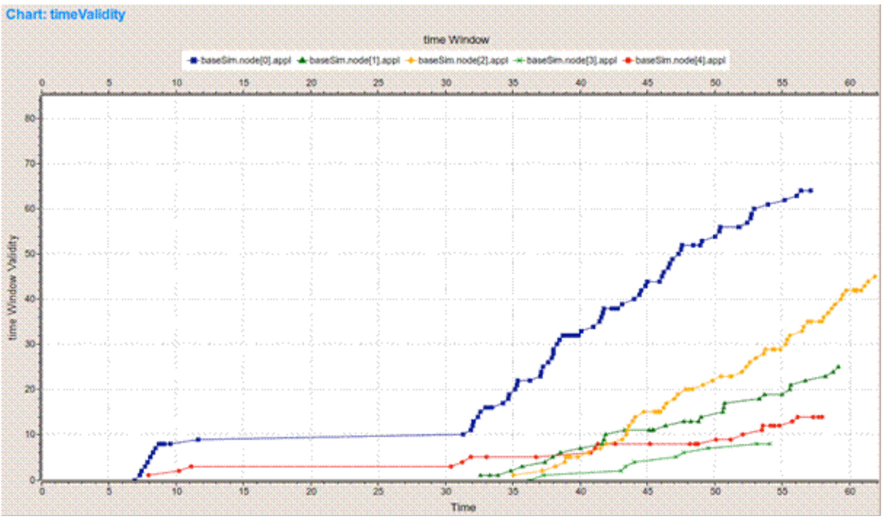

Fig. 4: Packet measured for Time Window.

Figure 5 shows when packets are in a true state. We can notice that the horizontal line in the graph correspond to the false state or VW-Expiration or TW-Expiration states. This case is similar to the TW graph. After 45 ms we notice that the packet is no more in a VW, but in a VW-Expiration state or false-state.

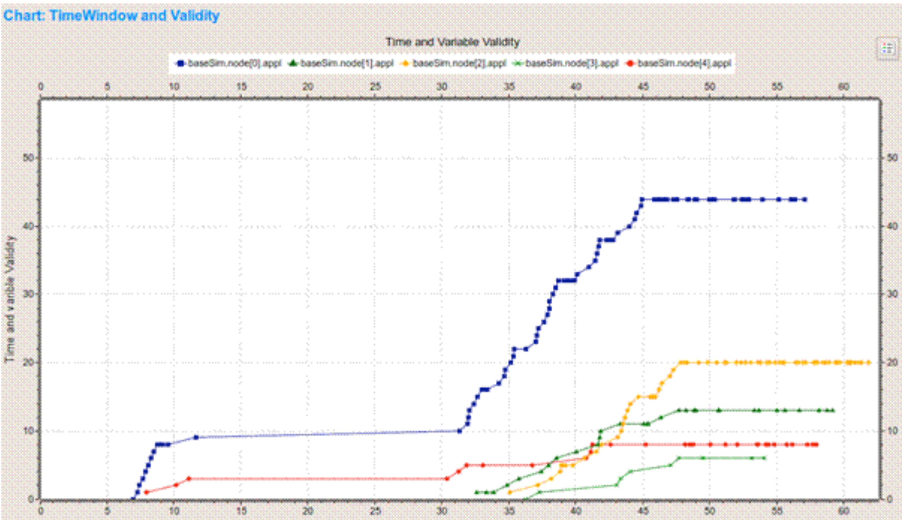

Fig. 5: TW and VW combination.

The simulation results prove that the proposed temporal mechanisms enable to have temporal information that can be used to locate the processes who do not respect the temporal constraints. These temporal information's are used to know the validity of the information.

5. Conclusions and future works

This paper has presented temporal description of time windows and variable validity time window to know the data's temporal statuses. These mechanisms enable to know, if the data temporal validity is correct, if this later can be used or not and where is located the temporal error (in the production, transmission or consumption steps). Simulations applied to sensors networks have been developed.

Theses temporal mechanisms can be used for different type of networks and real tests should be done in the future to validate these later in large sensors networks.

Acknowledgements

Part of this work has been supported by *Instituto de Telecomunicações,* Next Generation Networks and Applications Group (NetGNA), Portugal, and by Luso-French Program of Integrated University Actions (PAUILF 2010) – Action No. F-TC-11/10.

References

1. B. Fontan, S. Mota, P. de Saqui-Sannes, T. Villemur, "Temporal Verification in Secure Group Communication System Design", The International Conference on Emerging Security Information, Systems, and Technologies, October 2007, pp. 175-180.
2. Christoph Barz, Markus Pilz, Andre Wichmann, Temporal Routing Metrics for Networks with Advance Reservations, Eighth IEEE International Symposium on Cluster Computing and the Grid, May 2008, pp. 710-715.
3. Elisa Bertino , Elena Ferrari, Temporal Synchronization Models for Multimedia Data, IEEE Transactions on Knowledge and Data Engineering, July 1998, pp. 612-631.
4. Haitao Liu , Rajiv Gupta, Temporal Analysis of Routing Activity for Anomaly Detection in Ad hoc Networks, IEEE International Conference on Mobile Ad Hoc and Sensor Systems, October 2006, pp. 505-508.
5. Hongsheng Li , Sumin Liu , Bing Hu, Research on Node Sleep/Wake-Up Mechanism in WSN Based on Fuzzy Energy Control, Second International Conference on Intelligent Networks and Intelligent Systems, November 2009, pp. 11-14.
6. Hung-Ying Tyan , Chao-Ju Hou , Bin Wang, A Framework for Provisioning of Temporal QoS in Core-Based Multicast Routing, 20th IEEE Real-Time Systems Symposium (RTSS'99), December 1999.
7. Ilenia Tinnirello , Sunghyun Choi, Temporal Fairness Provisioning in Multi-Rate Contention-Based 802.11e WLANs, Sixth IEEE International Symposium on a World

of Wireless Mobile and Multimedia Networks (WoWMoM'05), June 2005, pp. 220-230.

8. Kashinath Basu , Frank Ball, A Scheduling Architecture for QOS and Temporal Mapping, First Asia International Conference on Modelling & Simulation (AMS'07), March 2007, pp. 258-263.
9. M.A. Cardenas , I. Navarrete , R. Marin, Efficient Resolution Mechanism for Fuzzy Temporal Constraint Logic, Seventh International Workshop on Temporal Representation and Reasoning (TIME'00), July 2000.
10. Pandurang Kamat , Wenyuan Xu , Wade Trappe , Yanyong Zhang, Temporal Privacy in Wireless Sensor Networks, 27th International Conference on Distributed Computing Systems (ICDCS '07), June 2007.
11. Roman Obermaisser Temporal Partitioning of Communication Resources in an Integrated Architecture, IEEE Transactions on Dependable and Secure Computing, April 2008, pp. 99-114.
12. Song Fu, Cheng-Zhong Xu, Quantifying Temporal and Spatial Correlation of Failure Events for Proactive Management, 26th IEEE International Symposium on Reliable Distributed Systems, October 2007, pp. 175-184.
13. Tommaso Cucinotta , Gaetano Anastasi , Luca Abeni, Respecting Temporal Constraints in Virtualised Services, 33rd Annual IEEE International Computer Software and Applications Conference, July 2009, pp. 73-78.
14. Vincent S. Tseng , Kawuu W. Lin , Ming-Hua Hsieh, Energy Efficient Object Tracking in Sensor Networks by Mining Temporal Moving Patterns, IEEE International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing, June 2008, pp. 170-176.
15. You-Chiun Wang , Yao-Yu Hsieh , Yu-Chee Tseng, Multiresolution Spatial and Temporal Coding in a Wireless Sensor Network for Long-Term Monitoring Applications, IEEE Transactions on Computers, June 2009, pp. 827-838.