Modelling by Petri Nets of an active product for the Security Management of Hazardous Products

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Abstract. *This paper presents and proposes a model by coloured Petri Nets of an innovative concept of active products which are equipped with a platform of wireless sensor networks and with an ambient communication in order to increase security, in a context of ambient intelligence of a deposit for chemical substances. The concept of active products supported by a model that we propose, offers the possibility to objects to interact between them in an autonomous, transparent and intelligent way, without any human help. The organization of communication stream is established by a set of defined messages. Behaviour evolution of every active product was modelled by hierarchical Petri Nets.*

Keywords. *Active product, Distributed system, WSN, Petri Nets, Security, Chemicals product.*

1. Introduction

Accidents in chemical industry became more and more frequent due to the absence of appropriate safety measurement notably in goods storage and handling field. This subject attracted the interest of several research projects; that we mention for instance the COBIS project [19] which is developing a new approach to business processes involving physical entities such as goods and tools in enterprise environments. The intention is to apply advances in networked systems to embed business logic in the physical entities. By means of embedding a communicating logic in simple physical entities this project improved the networked systems to finally create cooperative particles from which came out the name COBIS (Collaborative Business Items). These particles were incorporated into various application contexts particularly in industrial surveillance sector of dangerous products. Also, the research laboratory of

the Lancaster University [1] conceived, in the same objective, cooperative particles with perception, analysis and communication capacities that operate by information sharing principle.
Besides, one work led by the laboratory TecO University Karlsruhe of Germany and the MIT [2], display the concept of intelligent objects in the management of the integrity of written documents (Files, notes, documents, reports …) to respect restricted accesses and keep the track of the changes in a physical or electronic document. The CHAOS [3] project also leaned on the approach intelligent object to secure the exchange of the information in the distributed systems.
Finally, in a security purpose our work involves transforming products with dangerous nature into a communicating entity allowing the surveillance of its circle of acquaintances while collecting the information from its environment.
In this paper, an internal model of an active product was developed through the graphical and mathematical modelling tool: coloured Petri Nets, and then was validated by the simulation software CPNTools [20].
Our paper is organized as follows: after the introduction, the second part presents the concept of the active product for the security management. The third part introduces the cooperation between products. Finally a last part exposes the Petri Nets proposed model of the product and its cooperation environment.

2. The concept of the active product

Active product concept consists in supplying perceptions, memorization, treatment and action capacities in a physical entity [4][5][6]. It consists in conferring on the product an active and participative role in decisions and information streams engendered in a production or a logistic system, according to transformation, movement, maintenance, storage, transport, usage and recycling objectives. This concept is shown in our application by integrating a sensors platform in every chemical container with a hazardous substance, therefore, upgrading it with interaction capacities in the middle of its action environment.
If two particles are in the same field of communication, they communicate between them through messages sent by radio frequency. So, a particle can communicate with the administrator and the operator in the same way. Besides, particles can take advantage of services in the environment if it happens they come near a Wbridge, which interfaces the wireless environment to Ethernet / internet network as it is indicated the figure 1.

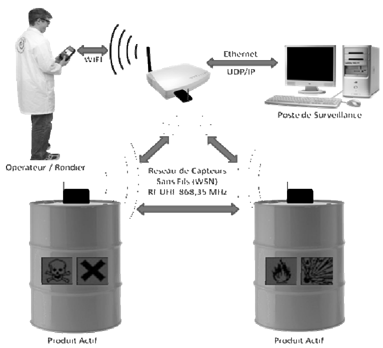

Fig. 1. Ambient system of Active Security management

2.1. Security rules

To insure a good surveillance to the product, three safety levels were established: (G) good level, (A) average level, (D) dangerous level. Determining security levels results after applying some security rules.
These last ones are divided into three categories:

- *Static Rules:* They are rules that engages the product alone in its environment, This product measures some values defining its safety level such as temperature, humidity, shock, luminosity … in order to keep itself in a stable sane state, these values shouldn't exceed certain limits min or/and max.
- *Dynamic rules:* they are rules related to the product by itself considering its state evolution through time. For example some product could not be affected if they reach a certain temperature threshold but the fact of reaching it several times in a period of time can bring the product in alarming state.
- *Community rules:* every product can have compatibility constraints with other ones of different nature. This incompatibility is established from the security symbols and also from risk and safety phrases according to the European directives 67/548/EEC. On the other hand, the manipulation of certain product requires an operator with specific fitness and aptitude; consequently, a product needs a well determined operator quality.

3. Active products cooperation

As mentioned above the active product is endowed with perception, data processing and action capacities; it does interact in its environment by sending messages.

3.1 Exchanged messages

Communication between products works by using several types of messages which are sent by a broadcasting mode and classified according to their role they are intended to perform as indicates figure 2.

3.2 Registration messages

This part is intended to announce the product in the community; we proposed for this purpose two types of messages: CTR (control Time Stamp Request) message which declares to the administrator the introduction of the product in the network and AckCTR which is an acknowledgement message sent by the administrator after the reception of the CTR.

3.3. Configuration messages

After registration the product has to hold a configuration allowing it to interact correctly in the community ; This configuration concerns the type of product regarding its danger classification (safety symbols) and its static, dynamic and community rules as well ; This distribution led us to propose three types of Not Configured messages emitted by the product.
NCF0: If the product does possess neither its classification information nor its security rules.
NCF1: If the product only possesses its classification information.
NCF2: If the product only possesses its security rules configuration.
From the administrator side, this latter answers by the appropriate configuration command messages which are respectively:
CMD1: Message supporting the configuration of the product classification.
CMD3: Message supporting the security rules configuration.

3.4. Internal surveillance messages

Once the product is correctly configured; it becomes completely capable of surveying its neighbourhood.
Any environment modification breaking individual or mutual security rules must be detected, diagnosed and has to generate external actions allowing to recover the actual safety level by actions or directed information of the ambient environment. These interactions are made by means of the following messages:
GRE: It is a greeting message carrying specific product information (name, safety symbols) and has a further role contributing to the calculation process of the distance separating two active products.
RSI: This message contains the value of the power difference signal. It is sent from a particle which has already received a GRE message. The particle calculates the difference of signal between both broadcasting and receiving particles and then send the result through RSI.
INA: This message carries the ambient values measured from the product sensors platform.
CFG: this message contains the specific configuration in the active product; it is emitted by this last one after an administrator request.
SER: This message includes the configurations of security rules.
ALE: It is sent in case of alert; this message reports to the administrator about the defective security state. In our model we separated this alert situation into three cases; products incompatibility alert which is represented by ALE1 message, alert generated after an RSI message analysis and it is represented by ALE2 message and finally ambient value alert which is represented by ALE3 message.
The administrator participates in the communication part by specific command messages.
CMD2: The administrator requires the configuration of the active product through this message.

CMD4: Also the configurations security rules are asked via CMD4.
CMD5: With this message the administrator collects the product specific ambient information.

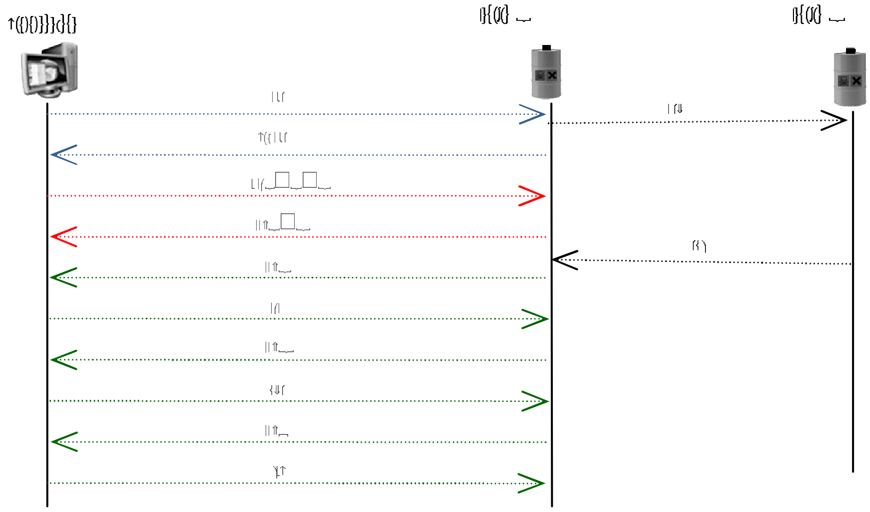

Fig. 2. Sequence diagram between products and supervisor

4. Modeling by Petri nets

A Petri nets is a bipartite graph including two sorts of knots: places and transitions connected by arcs. Places contain tokens which pass from a place to the other one by firing transitions through firing rules [7]. The distinctive characteristic of the Petri nets is its graphic aspect allowing a simple evolution of the models while having solid mathematical bases [8]. In the Colored Petri nets [9], [10], [11], [12] the descriptive aspect of the Petri net is increased by associating colours to tokens, places and transitions. Every token has a colour which allows him to be distinguished from tokens carrying other colours. A set of colors is associated with every place and determines the token colors that can be deposited in the place. For every transition is associated a set of the colours too which represents the various manners to fire the transition [13]. In timed Petri nets a duration of firing is associated to the place (timed place Petri net) [14] or to the transition (timed transition Petri net) [15]. In those cases the token is unavailable during all the delay period; it is reserved. Let us note also, that in certain references it is possible to combine timed place Petri nets and timed transition Petri net to obtain a timed place transition Petri net [16].
Several works opted for the Petri nets as a modelling tool in for example communication systems and logistic chain [17] proposed a model of TCP / IP communication behaviour; [18] presented a model of a network controlled systems.

5. Model of the Active Product

The objective of our work is to represent the behavior of the active product and the stream of messages through a wireless network; the tool CPNTools was used to simulate the model by colored Petri nets in hierarchical structure. Figure 3 represent an internal model of the active product, in this structure the transitions holds a description of a functioning part of the product. The place NETWORK corresponds in the matter of fact to the wireless communication network and collects messages emitted and received messages from all the existing products; let us note that messages are sent in broadcasting mode. This characteristic is carried out by the transition "broadcasting messages" which puts tokens in all the places corresponding to the various products. Messages intended for a specific active product will fire its own “RECEIVED MESSAGES” place. Circulating messages will be represented by coloured tokens. This hierarchical structure is also applied to the administrator.

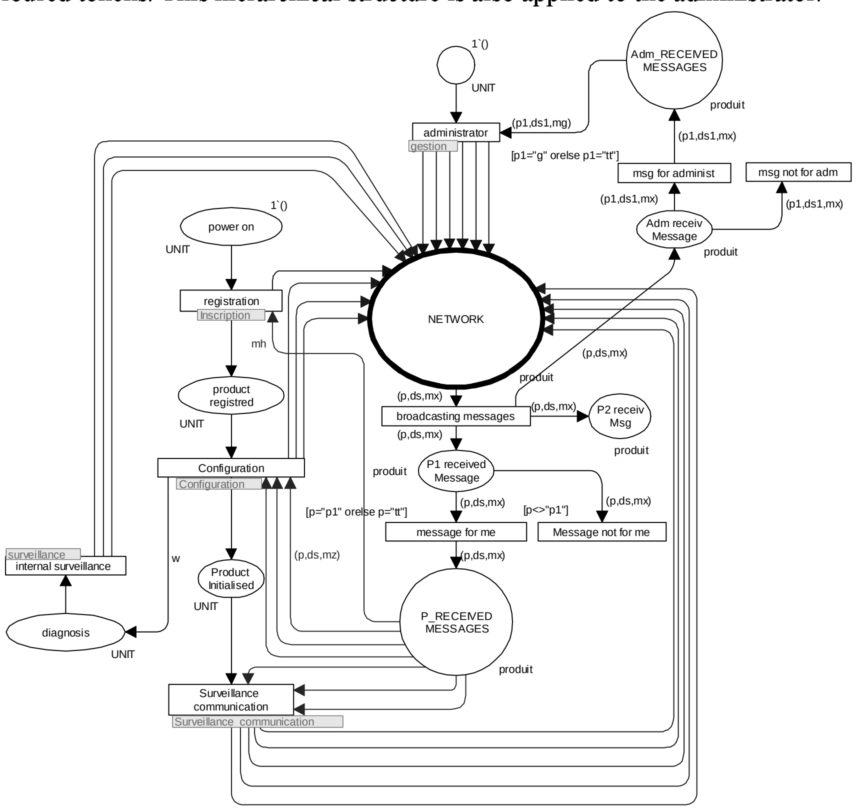

Fig. 3. Petri nets of the actif product model

5.1. Registration Part

In this part the product announces in the network by sending of a discovery message detected by the administrator. As it is indicated in the figure 4 after switching on the particle a token CTR will be put in the NETWORK place indicating this way the fact of sending a CTR message, the transition "**Ack**" will be valid if a token AckCTR shows up in the RECEIVED MESSAGES place. The absence of acknowledgement token will lead to the validation of the "**Ackbar**" transition and the same process will be repeated over again. The feature of this petri nets insures a registration of the product in the network.

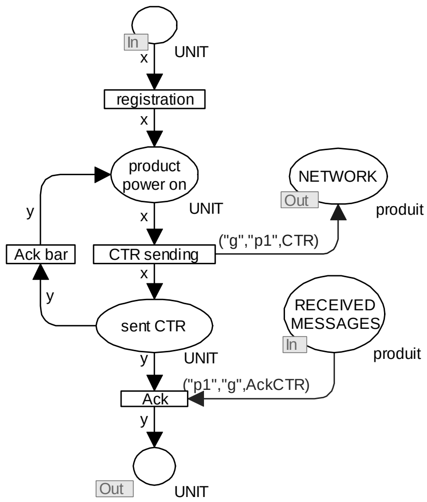

Fig. 4. Registration Petri net

5.2. Configuration Part

"Cbar. Sbar", "Cbar.S", "C.Sbar" and "C.S" transitions defines the product configuration state; they are fired if the product does not have either general configuration or safety rules configuration. According to the type of necessary configuration the corresponding transition will be fired and an appropriate NCF token goes to the NETWORK place. If the good CMD token appears in the RECEIVED MESSAGES place, another token passes on the "configured product" place otherwise the transition "CMDbar" will be validated and as a consequence another token NCF will be sent again. The Petri net for this part is shown in the figure 5.

After the accomplishing the configuration part the product is now ready to operate in the network. A token will pass to communication and diagnosis place to activate respectively the communication and the internal surveillance part.

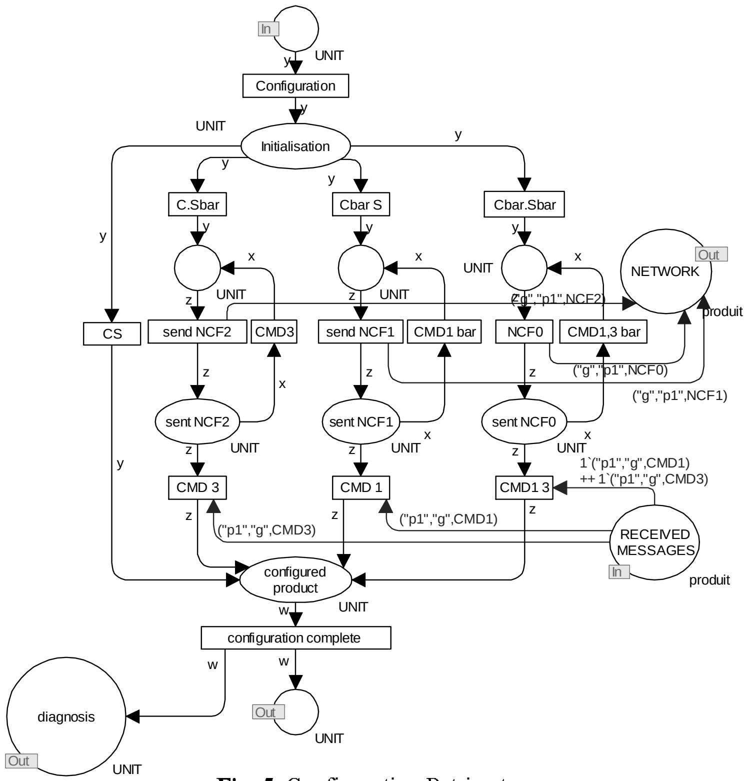

Fig. 5. Configuration Petri net

5.3. Surveillance and communication part

The petri nets surveillance and communication acts according to the type of different received messages; every token representing a message will fire its corresponding transition as it is indicated in the figure number 6:

GRE transition: the particle decides whether there is an incompatibility situation or not. This is expressed by either transitions «**comp**» referring to compatible product and «**Incomp**» referring to incompatible product and which respectively valid RSI or ALE1 transmission.

RSI transition: the information which carries the RSI message will be analyzed to decide on whether the distance separating the corresponding products is in the danger degree; if so, an ALE2 message will be sent.

CMD transitions: every transition processes a specific command. Firing each one of it will activate the transmission of appropriate messages that are CFG or INA or SER.

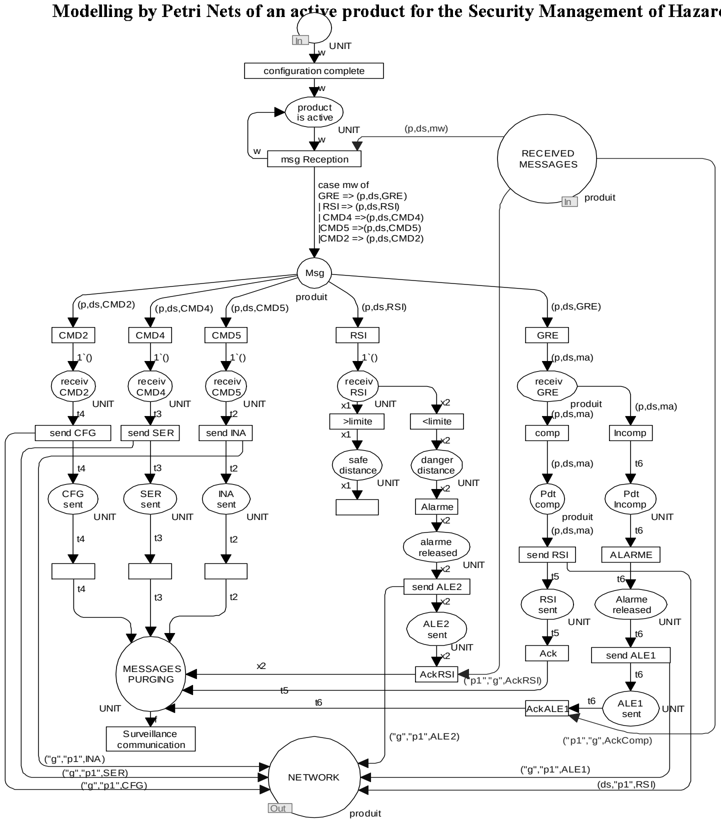

Fig. 6. Surveillance and communication Petri net.

5.4. Internal surveillance part

In this Petri net each sensor was represented by a transition which generates the ambient values measurement. Those values will be interpreted with the established safety rules. Static safety rules were performed by a function that locates the measured sensor value into its corresponding safety level. We gave below an example of the temperature sensor static rule:

If temperature is < 10°C and >40°C then the product state is Dangerous (D)
If temperature is < 15°C and >30°C then the product state is Average (A)
Else the product state is Good (G)

Dynamic rules were represented by the purple part of the Petri net as it is indicated in the figure number 7. It operates by counting the number of time a specific value of temperature was reached. If it does exceed a preset it generates a D token which refer to a dangerous safety level.

Finally, the "**final state**" transition will analyze all results coming out from each sensor and its safety rules and then decides the final product safety level. This fact operates as follows: safety level is considered Dangerous if at least one (D) tokens appears in the functions results, otherwise, safety level is considered Average if at least if one (A) token appears in the functions results, if not safety level is considered Good. According to the final safety level appropriate messages will be transmitted with the necessary information about the ambient values which are GRE for (G) and (A) levels and ALE3 for (D) level.

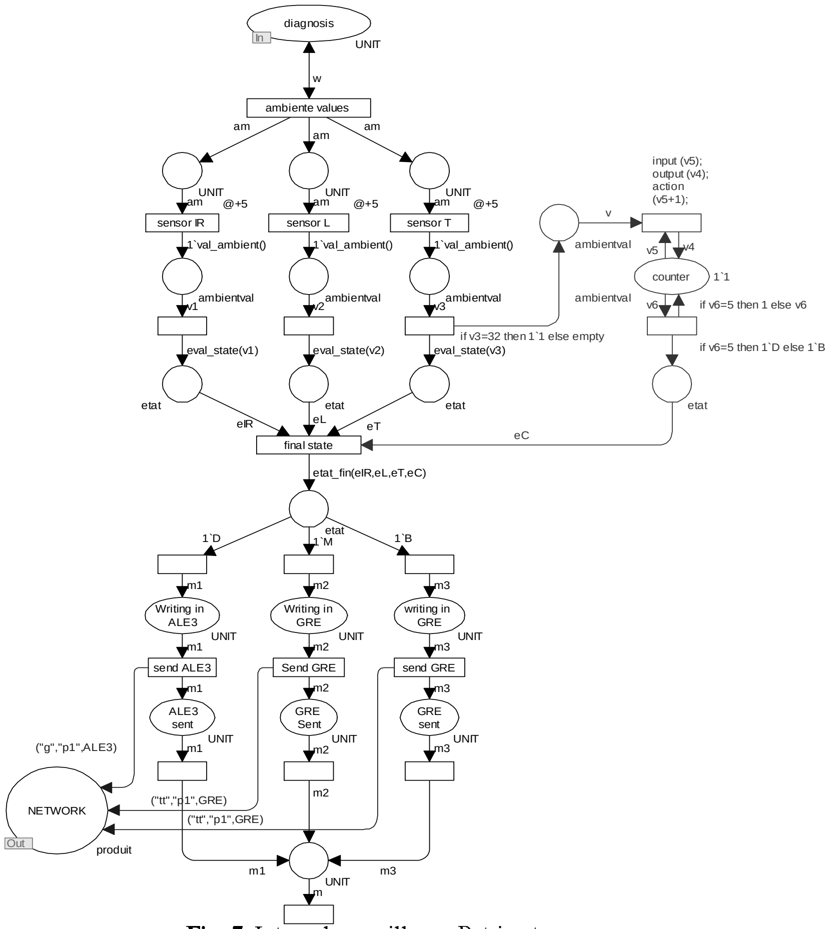

Fig. 7. Internal surveillance Petri net

6. Conclusion:

During this work, we proposed an active product model which was represented by a hierarchical coloured Petri nets. The objective of this Petri nets is to the information stream and to observe its impact on the active product.

The hierarchy allows to display the evolution of every stage of the active product functioning and the influence of the communication network as well. An improvement at the internal surveillance part can be reformed by the application of Fuzzy logic rules, particularly, at the evaluation of the product security level. This model can grow rich by adding a human operator's model or equipments model directly related to product manipulation which may lead to a hazardous situation.

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Comments for the Authors

Constructive comments to the author(s) would be appreciated.

This paper proposes a security management of hazardous products.
It is in fact a little bit difficult to understand exactly the approach developed by the authors.
After the two first sections, which are descriptive, the third section describes a communication protocol. Could you please explain with more details what is the strategy used, why did you choose this strategy, and possibly give some performances (results)…
The problematic linked with the use of the WSN should be developed too: are there some constraints (bounded time, loss of transmission…) which should be taken into account in the approach proposed?
A section on final results and what was brought by the methodology should be added in the final paper.