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MODELLING AND SIMULATION OF THE NEW EUROPEAN TRAIN CONTROL SYSTEM

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Abstract. This paper deals with a description of the modelling and simulation of the new European Rail Traffic Management System (ERTMS). The general structure of the project is illustrated and the modelling approach is explained.
Different system views were integrated in the entire model which was designed and evaluated by Petri Nets. Based on an informal (natural language) specification a formal net representation was created. The investigation of static as well as dynamic system behaviour is possible. The model consists of a process, scenario and functional account. The aspects of reusability of subnets are mentioned.

1 Introduction

The aim to realise an European Rail Traffic Management System (ERTMS) is motivated by the problems of the frontier crossing of trains. Up to now each railway administration forces its own train control system. In other words it is necessary to change the train traction for passing the border or to equip the engine with many different systems on board as national solutions of the countries it will pass. In consequence the first solution costs a lot of time the second a lot of money. In order to avoid this it is important to define an unique train control system. It means in detail that the train can pass the frontier without changing the engine. Furthermore it is not necessary to change the engine-driver, because an uniform signalisation is provided for the man-machine-interface (MMI). This case is called interoperability.
The development of an interoperable future train control system is characterised by high complexity. Different kinds of interests related to the implementation strategy and to the existing functional environment of the system has to be reflected on. Furthermore it is necessary to look at the safety critical aspects for the train control system. The interests in modelling and simulation of the new system are focused on the verification of the standardised interface description and the investigation on the integration of the new system to the existing interlockings and regulation systems.
The implementation of the new train control standard will be the basis for the unrestricted border crossing services as well as for the liberal using of the railway network by several railway companies. Appropriate European directives are in preparation.

2 The system structure

The main units of the ERTMS are the onboard and trackside systems. The onboard system supervises all functions realised on the train and communicates with the trackside system. So, for the communication purposes, the onboard components cover the radio installation and devices for reading of beacons, so-called balises. Beside this there exist special interfaces to the existing national train control systems, called Specific Transmission Module (STM). Also the movement of ERTMS fitted out trains on conventional tracks is possible by the STM's.

The heart of the trackside system of ERTMS is the Radio Block Center (RBC). The RBC communicates with the train, the trackside installations (for example level crossing), the interlocking and the regulation. Evaluating the information given from the interlocking and the regulation the RBC gives movement authorities, orders and instructions to the train.

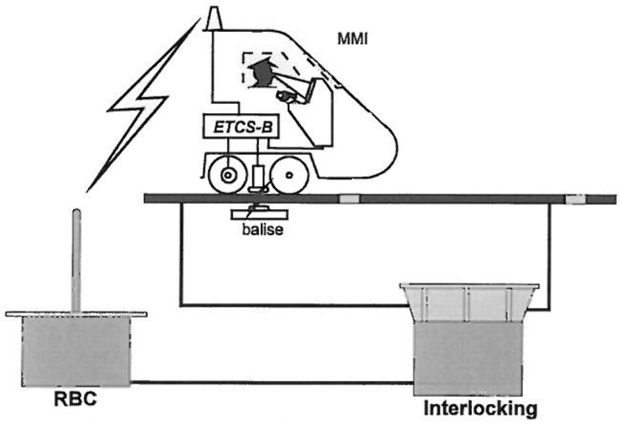

Figure 1: European Rail Traffic Management System (ERTMS)

The ERTMS identifies three functional application levels. They are defined to provide the railway companies with systems which are adequate for their typical national environment. They also ensure downward compatibility. Using the different levels, fall back strategies and migration processes are supported. The main characteristics of these three levels are listed beneath:

	Level 1	Level 2	Level 3
Technical Interoperability	**Yes**	**Yes**	**Yes**
Operational Interoperability	**Only with MMI signalling**	**Yes**	**Yes**
Physical signal trackside	**Yes**	**Optional**	**No**
Driver information	**Signalling trackside and optional cab signalling / MMI**	**Cab signalling / MMI and optional signalling trackside**	**Only cab signalling / MMI**
Radio Transmission	**No**	**Yes**	**Yes**
Train Integrity	**Checked trackside**	**Checked trackside**	**Checked by train itself**
High performance blocks (virtual short sections) possible	**No**	**Yes**	**Yes**
Moving Block possible	**No**	**No**	**Yes**

Table 1: Characteristics of the different ERTMS levels

Under certain circumstances the ERTMS could provide also mixed traffic of different application levels.

3 The Project: The formal system specification

Based on the informal (textual) System Requirement Specification (SRS) it is the goal to create a formal system model in order to verify the specification. The requirement of a safe system demand the proof of the correct system behaviour specification. The most important part of the model is the interaction between onboard and trackside. Furthermore the interface to the environment for the system stimulation is modelled.

In order to proof the system behaviour a formal description in a mathematical sense is important. Either the correctness, logic behaviour and concistency of the model have to be checked. Not only the static aspects moreover the system dynamic have to be considered. On account of this Petri nets were used for system modelling.

3.1 Specification in three phases

The base for the modelling was the system requirements specification at the state of the art. The specification was available in textual form. This informal representation is not easy to percept and has all adjectives of the natural language: incompleteness, incorrectness, ambiguousness and contradictions. Moreover the static structure and dynamic behaviour is not provable.

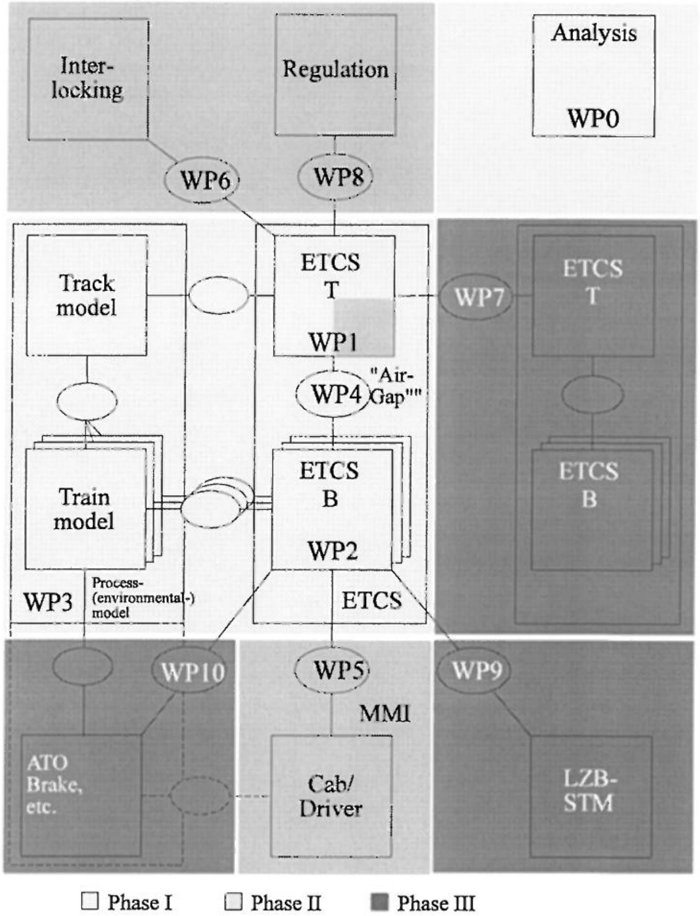

Figure 2: Project phases and workpackages

The aim was to model the system with Petri Nets. The benefit is a formal representation and the integration of static and dynamic aspects in an unique model. Moreover it is possible to simulate and to analyse the model. In order to handle the project efficient three phases were defined as shown in figure 2. A central part is the interaction of the on board and trackside equipment and the communication over the 'air gap'. For the environmental behaviour no explicit specification exists, but it was important to model that interface for the dynamic check.

3.2 Modelling of the ERTMS

On different levels the model represents different appearance of the system. The model incorporates the following paradigms:

- *Process*

  The representation of the (technical) process is oriented at the system behaviour. In the general view the interfaces, the objects (like e.g. regulation, interlocking, train or radio block center) and the global behaviour is included.

  For example the process view in phase I (compare fig. 2) represents the interaction between the Trackside/RBC (ETCS-T, WP1), On Board (ETCS-B, WP2) and environmental part (WP3) of the model.

- *Scenarios*

  The scenario view consists of walk through strongly connected activities. That means in detail the closely related activities of mainly operational type which are necessary for e.g. entering to RBC, RBC area change, joining, splitting, shunting, etc.

- *Functions*

  The functionality is shown in this more detailed level of the model. Some functional modules can be used in different scenarios. They are stored separately for reuseability. The are then called functional blocks.

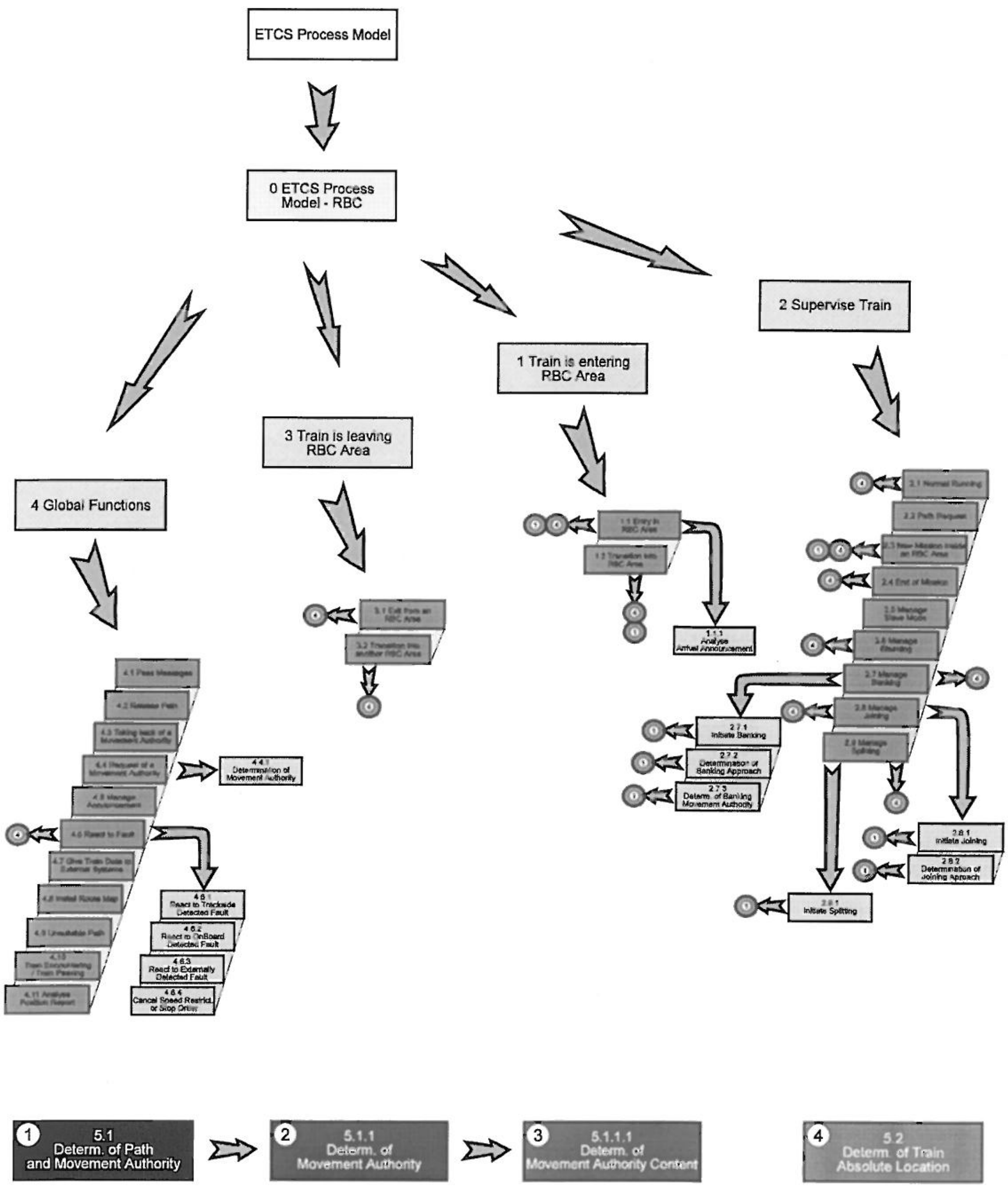

Figure 3: Structure of the RBC Petri Net model

Figure 3 shows the structure of the RBC Petri Net model. Without discussing details the composition of the nets can be identified. On the upper level the general process model is drawn with the relations between trackside, on board, environment and communication. The refinement of the general process model is the specific trackside/RBC process model. The next decomposition steps generates four models: On one side we have the representation of 'global functions', on the other side the entering, the running of a supervised train in a RBC area and the exit from or the transition into another RBC area. Below that level a number of more detailed nets exists. This is the scenario and functional level. The refinement of the 'Supervise Train' model represents for example special scenarios for shunting, joining, splitting, etc. The reuseability of nets is indicated by the arrows and little circles which stands for the 'functional blocks'. These blocks can be universally used in different nets. Examples are shown on the bottom of figure 3.

However hierarchical as well as modular structures in the net model were developed. The advantages of the entire description are seen in receiving a consistent description useable for simulation, validation and verification. This is founded on two basic aspects. First, we have established an efficient integration of the three paradigms mentioned above. Second, some special problems can be treated in local and separated parts of the model, e.g. isolated scenarios or functions.

3.3 Simulation of the ERTMS

Using the consistent and complete specification based on the formal notation of Petri Nets, simulations can be performed. Thus each single scenario can be checked on the right behaviour and fault state analysis can be generated. Like this some major problems of the original specification and eliminated with the appropriate changings in the model specification. These lacks of functionalities could not be detected in the written human natural language documents.

In the next step also the behavioural interaction between different scenarios as well as parallel activation of scenarios will be established. It will show the dynamic behaviour of the overall system.

The already existing formal and consistent specification in the system model does imply only low effort to extend the model to run simulations. This is depending of the Petri Net representation.

4 Conclusion

As shown, the general approach for the model structure is new in this large-scale project. The scenarios were integrated in the general structure of the model and not anymore separated in different documents. The consideration of functional blocks offers good possibilities for reuse. Altogether we get good possibilities for scenarios check as well as checks of the complete system behaviour.

The improvement of the specification process requires the consequent and complete application of the formal Petri Net representation. The textual explanations should only be used as additional information. Otherwise the usage of the natural language documents implies the well known problems.

Further work will pointed out the possibilities for system verification. The capability to check simple scenarios as well as the interaction between them up to proof of the correct behaviour of the entire system is the benefit of the created formal model.

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