Network control for improved performance A new concept for on-line scheduling and dispatching

F. Makkinga & L. Zigterman
Holland Railconsult
Infrastructure Division
The Netherlands

Abstract

Over the last decade, the number of trains has increased to meet the required transport capacity. Today, an average of 6000 trains per day must be managed by Netherlands Railways. The result is highly intensive usage of the infrastructure. Relatively minor disruptions can lead to major distortions, if not handled appropriately. To manage this volume of train traffic effectively, and to maintain the (demanded) quality in terms of reliability and punctuality, the route-setting process has altered. We have seen a shift from dispatching routes manually, on the basis of a timetable, towards automatic route setting using an up-to-date route setting plan. With the assistance of the automatic conflict detection and decision support systems, this route setting plan can be kept up-to-date and free from conflicts. All potential conflicts are handled centrally by the train dispatcher.

To fulfil the required transport capacity for the next decade, a new concept in train management is required. This new concept is known as Network Control. The effect which can be achieved with Network Control is handling larger numbers of trains whilst at the same time increasing performance. The route setting process will then shift from automatic route setting towards route management. Network Control distinguishes four layers and a generic architecture for each layer. This architecture forms the basis for the distributed handling of potential conflicts and resolution.

1 Introduction

Mobility is increasing throughout Europe. The same applies for the Netherlands. Netherlands Railways and the national government have set out to facilitate a significant expansion of rail traffic, by the year 2020. This objective must be achieved at – relatively – limited cost. Furthermore, the following constraint also applies: the quality of the delivered transport product must be improved. Today's passenger transport performance cannot be described as excellent.

Research is focusing on methods aimed at enhancing utilisation of the existing rail infrastructure. On the one hand, possibilities are being investigated for increasing transport capacity for each individual train. On the other hand, the search is on for ways to increase train numbers. In our opinion, projects like ETCS and ERTMS are both focusing on this area.

We expect the requirements imposed on Traffic Management systems to further evolve towards delivering improved performance. One of the building blocks will be controlling train services, described by us in this paper as Network Control.

This paper presents the potentials and objectives of Network Control, as well as describing how it can be implemented and how to migrate from the current train control systems to Network Control systems.

2 Implementation of control systems at Netherlands Railways

At the end of the 1980s, Netherlands Railways started on a large-scale programme for modernising control systems. Now, more than 10 years later, the entire Dutch railway network is operated by an integrated computerised control system VPT (Renkema, Vas Visser [1]). Information interchange between the computer systems is achieved via a national network. Train planning is present in electronic form within the systems. As a result, train routings, for example, can be set fully automatically. As a consequence, the train dispatcher is able to anticipate what is going to happen next. The task of the train dispatcher has undergone a shift from implementation to planning routes. Figure 1 shows a concept for a train control system. One key task is keeping the electronic planning free from conflicts. If in the event of a conflict choices are not made in time by the train dispatcher, problems will arise. In such a situation, the automatic systems are unable to set routings in time. As a consequence, trains are halted by signals at stop, and delays become longer.

To shift from planning routes towards route management the concept of network control is needed. This will be explained in chapter three.

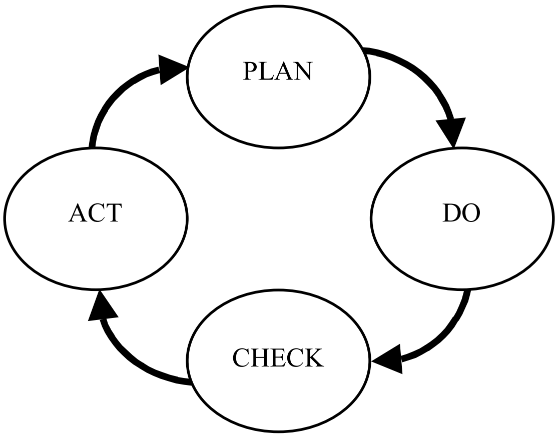

Figure 1: Concept of train control system

This figure represents a quality circle consisting of four processes and the following implementation:

1. Planning (plan)
   The starting point is the operators timetable. This timetable is converted into a detailed plan. This plan describes what has to be produced, and how, when and where. Indications are for example given of planned times for train departure, on which track, how late the routing should be set, to which track, etc.
2. Implementation (do)
   The objective of the control system is to ensure that the plan is implemented as smoothly as possible. Implementation tasks are automated, wherever possible. As a result, the train dispatcher is able to concentrate more on the consequences of deviations, and if necessary adapt the planning, in good time.
3. Control (check)
   This process is focused on discovering in time the consequences of deviations in the actual process implementation as compared with the planned process. Whenever a deviation results in a conflict, the train dispatcher has to alter the planning. It is essential that conflicts be identified in good time, and reliably. In good time so that the train dispatcher can continue to anticipate ahead of events and reliably so that the planning can be correctly altered.
4. Adjust (act)
   The final process is aimed at selecting the measures and altering the planning. The choice of measures makes it possible to resolve or avoid conflicts. The space for a solution consists of a collection of measures whereby the initially allocated infrastructure is adapted in terms of time or location. Examples of adaptations in time are: alteration of train order or the moment of setting the

routing, and examples of location are: alterations of the routing or allowing the train to arrive at a different platform track.

In support of this new work approach by the train dispatcher, the conflict detection and decision support system has been developed (Stolk [2]). A number of practical tests (Makkinga, Metselaar [3]) have been carried out using this system, with positive results. The currently implemented CD/DS system offers the following functions:

a. Predictions
   Predictions for train traffic over the coming 10 to 15 minutes can be prepared that are sufficiently accurate and stable, and suitable for detecting conflicts (Makkinga, Metselaar [4]).
b. Conflict detection
   Conflict detection is able to detect and report to the train dispatcher the following three conflict types:
   1. Routing conflict
   2. Track occupation conflict
   3. Routing not available conflict
c. Decision support
   Decision support for the three conflict types above. As a result, the train dispatcher is able to select from a list of measures and alter the planning so that the conflict is resolved.

According to expectations, the CD/DS system will be introduced nationally over the next years, to support train dispatchers. After this Network Control is needed.

3 Network Control

3.1 Objectives

Network Control aims to contribute towards two objectives, namely a considerable increase in transport by means of a significant expansion in rail traffic and improved punctuality (figure 2). These objectives are subject to a range of constraints. A major infrastructure expansion is not desired, primarily on the basis of the heavy investments involved. Secondly, land use in the Netherlands is already intensive, and space for new infrastructure is very limited, at specific locations.

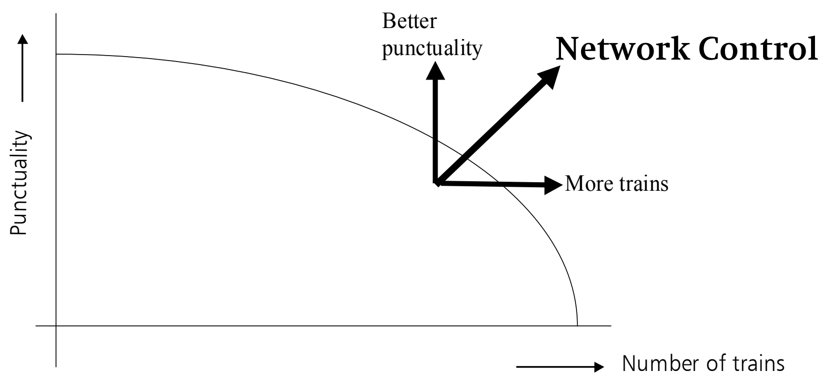

Figure 2: Objectives of Network Control

The transport organisations prefer to be able to deliver a diversity of products: long distance (intercity), short distance, even commuter-like services (stopping trains), long distance heavy goods ("bulk"), and high speed short distance goods with high values are just some of the extremes in the product spectrum.

A Network Control system must be able to accommodate this mix of transport products, not only those available today, but also emerging, innovative products. Transport operators are concentrating their requirements and wishes in terms of the products to be supplied, at the highest possible level. In other words: as few details as possible are set down in advance, in the production planning.

The Network Control system has been designed in such a way that the throughput of the train service is maintained, on the basis of the "keep them rolling" principle. This entails as much decentralisation of control as possible; at the very lowest level, each train for itself.

3.2 The concept of Network Control

Network Control is based on the following basic philosophies:

1. Division into a hierarchy of layers of control.
2. Implementation of the "plan-do-check-act" cycle at each level.
3. Embedding this cycle in a management system, driven by decision rules.

In the following sections, we start by describing the basic control loop and the concept of "decision rules", followed by a detailed description of the hierarchy.

Control loop

The control loop is constructed as follows:

Each train is provided with precise target information, in order to run according to the requirements of the most up-to-date planning (plan). This planning is used to select the appropriate train speed (do). If a train is unable to achieve its target (check) it immediately informs the Network Control (act). Any other events which could disrupt execution of the plan will also be signalled. The seriousness of the disruption factors must be rapidly classified. In the event of minor disruptions, primarily train speeds are regulated; the second step is to alter train sequence, modify the use of platform tracks or choose an alternative route.

In the event of major disruptions, such as obstructions, an alternative plan must be rapidly selected. In this way, Network Control can be qualified as Controlling for Throughput.

Each control level acts within specified frameworks for the levels of control higher up in the control hierarchy. These frameworks serve as the PLAN for the control level. As soon as the forecast progress of the process indicates that these frameworks are about to be violated, as detected by the CHECK phase, the next highest level of control is triggered. From this level, the ACT phase generally involves a modification of the PLAN of one or more building blocks, at the lower level. The progress of the process is subject to constant forecasting, to achieve this objective.

Decision rules

A generic architecture is applied for each layer, in which the management system can access the following data:

- The planning data which form the targets for the controlling process.
- A description of the current location subject to the control system.
- Rules for process control.
- The data relating to the current process status.

The generic architecture is outlined in figure 3.

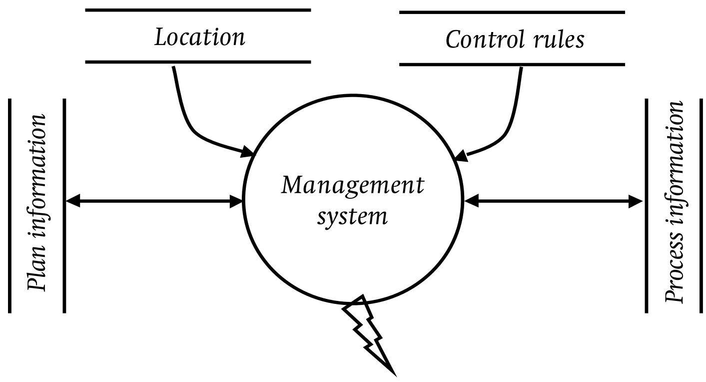

Figure 3: Concept of control rules

The rules for control are the crucial element; they lay down precisely how the control system "acts" in the case of various combinations of "planning data" and "current process status". The control rules can simply be added to, extended or altered by the Rail Traffic Management organisation itself.

Hierarchy of layers

Within Network Control, the following hierarchy of layers is distinguished:

- The individual train.
- A simple infrastructure building block, such as a passing place, a branch, a crossing, etc.
- A "pipe" = trajectory possibly with passing places, branches, etc. and the "node" = the intersection in station areas.
- The network, consisting of pipes and nodes.

Figure 4 demonstrates this hierarchy of layers.

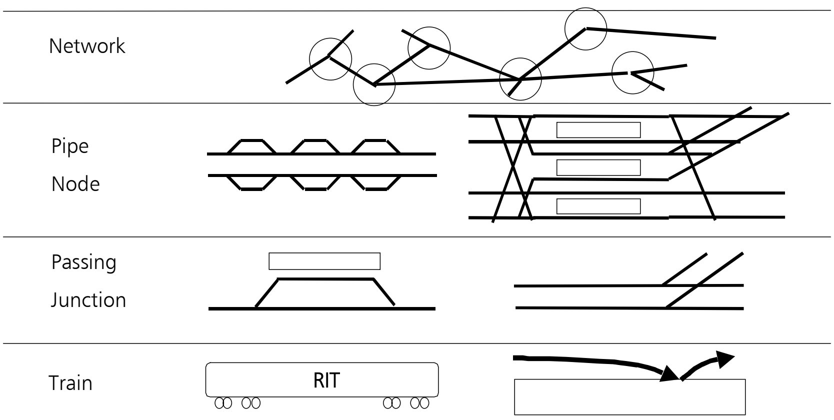

Figure 4: Hierarchy of layers

The table below (table 1) provides an impression of the "scope" of each layer.

Table 1: The "scope" of each layer

Network	100 trains	100 km	1 or more hours
Pipe / node	10 trains	30 km	¼ - 1 hour
Building block	2-3 trains	10 km	5 – 15 minutes
Train	1	3 km	1 – 5 minutes

Each layer must rapidly establish whether the plan is still feasible in respect of that layer. If this is the case, the layer exercises the necessary control, itself. If not, the system must move to a higher level. Rapid classification of the seriousness of the problem is a key necessity.

In figure 5 to figure 7, the generic architecture in figure 3 is applied to the specific layers defined in the infrastructure.

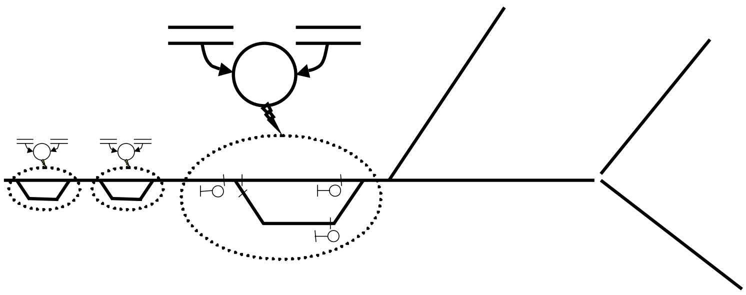

Figure 5: Local control

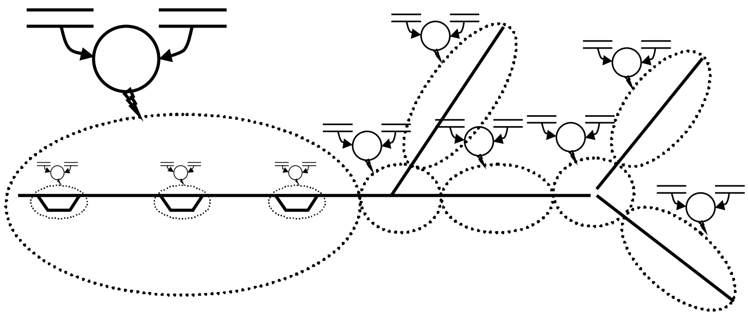

Figure 6: Second level of control (pipe, node)

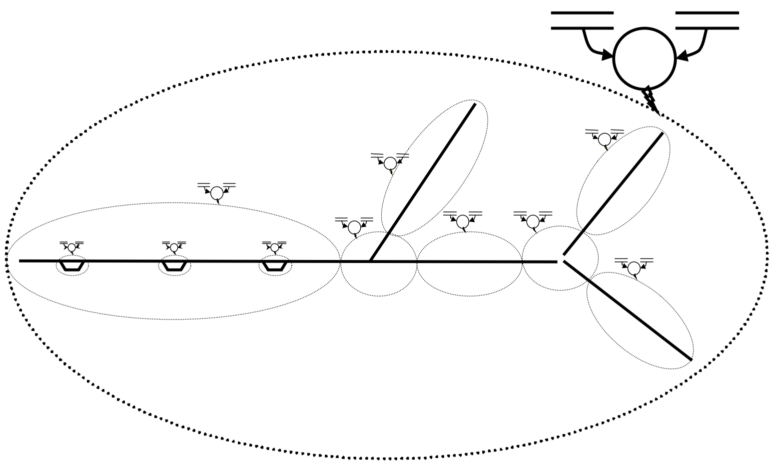

Figure 7: Application of all levels of control

4 Migration from trajectory to Network Control

The paradigm in the current control model is that decisions are taken centrally. The planning describes in detail how implementation will take place. In implementation, the train dispatcher is supported by simple automatic systems and in order to keep the planning conflict free, by the CD/DS system.
The paradigm for Network Control is that decision taking is distributed. Thanks to the hierarchy of Network Control, the planning targets can be shared amongst the thus generated control levels. By defining problem-solving capacity at each level, decisions within that scope can be taken autonomously.
In the place of a single central conflict detection and decision support system, a local control function can be defined at each level. As long as this control function is able to achieve the specified targets within the problem-solving scope, any necessary alteration can be carried out automatically, and locally. If this proves impossible, the problem is automatically passed on to the next highest level.

The introduction of Network Control will have a number of consequences for the current structuring of processes and technical systems. In planning, for example, details of routings will disappear. The planning will above all describe the objectives and parameters with which the finished product must comply. At one of the lower levels, for example, it will then be possible to determine the most suitable routing at the moment that a train actually requires a particular routing. In the event of a conflict, alternative routings can be selected and/or the speed of a train influenced in such a way that the conflict is avoided. The task of the train dispatcher will then shift from selecting measures to setting new targets and parameters.

5 Conclusion

Over the coming years, the transport of passengers and goods by train is due to increase further. The limits of available infrastructure and train control capacity are already in sight. By introducing far-reaching automation of control and adaptation, infrastructure capacity will be added without the expensive construction of new infrastructure elements. This new form of control and adjustment is described as Network Control. The concept is based on hierarchy in management, whereby a control loop is used at each hierarchical layer, according to which the actual control process is determined by decision rules. Over the coming years, this system will have to be further elaborated, the decision rules will have to be tested using simulation systems, and the hierarchical structure will have to be further detailed.

References

[1] Renkema, M. & Vas Visser, H. TRACE supervision system for dispatching and passenger information, Proceedings of COMPRAIL, pp 247-256, 1996.

[2] Stolk, A. Automatic conflict detection and decision support for optimal use of railway infrastructure; Purpose and concepts, Proceedings of COMPRAIL, pp 629-638, 1998.

[3] Makkinga, F. & Metselaar, S. Automatic conflict detection and advanced decision support for optimal usage of railway infrastructure: Prototyping and test results, Proceedings of COMPRAIL, pp 907-915, 1998.

[4] Makkinga, F. & Metselaar, S. Automatic conflict detection and advanced decision support for optimal usage of railway infrastructure: Results of pilot site operation, Proceedings of COMPRAIL, pp 1057 – 1064, 2000.