Automatic location-finding of train crew using GSM technology

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Abstract

Passenger carrier NSR (Dutch Railways Passengers) on a daily basis deploys approximately 1000 drivers and 1300 guards to run approximately 5000 trains. Normally speaking, the current deployment is in line with the crew schedule as laid down in the transport management system. This schedule is generally immediately (manually) updated to suit the situation. In the event of major disruptions, however, problems may occur as a result of which the disruption management organisation loses sight of the current personnel deployment. As a consequence, a situation can arise whereby the crew schedule no longer reliably reflects the current situation. This can lead to errors in the crew rescheduling and possibly to the cancellation of trains because crew have not been organised on time. For NSR this was an undesirable situation and the reason to launch the investigation into how this bottleneck could be solved. A research and development project was undertaken by NSR and Movares with the aim of developing a method for the automated detection of train crew on trains and the registration of deviations in respect of the crew schedule. During this project, a system was developed that – on the basis of GSM technology in combination with the monitoring of trains via the infrastructure – automatically detects which train crew members are located in which train. In the spring of 2009, a very successful test was implemented using the system.
Keywords: planning, crew scheduling, location determination.

1 Introduction

Dutch Railways, Passengers division (NSR) is far and away the largest passenger carrier in The Netherlands. Every day, NSR carries approximately one million

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passengers with approximately 5000 trains. NSR serves approximately 280 stations. The Dutch railway network covers a total length of approximately 5000 km, of which more than 2000 km are twin-track and almost 1000 km single-track.

1.1 Complexity

To successfully manage the complex transport process in The Netherlands, trains and the accompanying train crew are planned accurately to the nearest minute. Every train has train crew on board: one driver and one or more guards. Train crew change trains at the end of the train journey, or en route, at one of the approximately 30 larger stations. During their shift, train crew are not linked to a single route, but several times a day switch to trains operating on another route. Every day, approximately 1000 drivers and 1300 guards are at work in trains.

1.2 Management of the train service

The operational management of the train service is undertaken in collaboration between the operator (NSR) and the railway controller (ProRail). NSR monitors the deployment of train crew and wherever necessary makes adjustments (Makkinga [1]). The operational management is supported by a transport management system according to which execution of the timetable and the deployment of rolling stock and train crew can be monitored and as necessary adjusted. During the peak hours of the day, approximately 300 trains are operated simultaneously.

Due to the intensity of train traffic (short follow-on times) but also because train crew are not linked to fixed routes, train traffic and crew deployment are relatively susceptible to disruptions (Jespersen-Groth et al. [2]). In the event of major disruptions (intersections or track sections becoming blocked), the result can be that during the execution dozens or even more than one hundred work lines for train crew members have to be revised. A work line for a driver or guard describes on which train he or she is consecutively set to work today, together with the times and the stations. If a work line has to be revised, the responsible officer (the so-called crew dispatcher) comes up with the change, duly notifies the driver or guard in question by telephone, and registers the change (following acceptance by the driver or guard in question) in the transport management system.

1.3 Who is where?

For adjusting crew shifts, it goes without saying that it is crucial to know on which train or at which station a driver or guard is currently located. Normally speaking, the current deployment is in line with the crew schedule in the transport management system. This schedule is generally immediately updated if made necessary by the situation. For example, if current execution deviates from the schedule as in the event of a delayed train, or if the schedule requires adjustment, for example because it has been decided to run an extra train. In the event of major disruptions, however, the situation can arise that the crew schedule no longer reliably reflects the current situation. Train crew may then possibly be located on a different train or at a different station than shown in the crew schedule.

One major cause is the often poor telephone connectivity during disruptions, for both train crew who are required to notify passengers, and for crew dispatchers, who are hard at work rescheduling crew. This can lead to situations whereby the train crew themselves take decisions on their own deployment, without those decisions at that moment being known to the crew dispatcher or recorded in the crew schedule. It is also possible that in the event of major disruptions, changes to the timetable and crew deployment are not immediately fully processed in the schedule. The fact that the crew dispatcher has no clear picture of the current situation leads to errors in crew rescheduling, and sometimes even to the cancellation of trains because crew have not been arranged in time.

1.4 Automatic localisation of train crew

For the operational management of rolling stock deployment, a tracking and tracing system has been in use for a number of years, which compares the rolling stock schedule with measurements of actual rolling stock deployment, and as necessary, updates the schedule on the basis of the findings. This led to the need for a comparable method of detecting on which train a driver or guard is currently operational, comparing this information with the crew schedule, and as necessary, updating that schedule on this basis. Preferably, these processes should be fully automated.

2 Successful implementation of the innovation project

In the second half of 2008, on behalf of the Transport Control department of NSR, engineering firm Movares carried out an innovation study. This study aimed to identify the possibilities of determining which train crew members are on board which train in real time, fully automatically. The further requirement was imposed that no equipment was to be built into the train. Besides the already available PDA and GSM telephone, crew were not allowed to be supplied with additional equipment. As a result, the space for solutions was considerably limited. Within these parameters, the most likely solution for determining the presence of crew members on a train seemed to be matching position reports from trains with position reports from the GSM telephones of the train crew.

In January 2009, in a collaborative venture between NSR, NS Information Management & Technology (NS IM&T), Movares, SmartPosition and InTraffic, a development programme was launched. As client, NSR formulated the requirements and parameters. Movares submitted its knowledge of the railway infrastructure, and developed the system concept together with NS IM&T, the organisation that was also responsible for project management. Software company SmartPosition supplied its knowledge of GSM technology and, in close

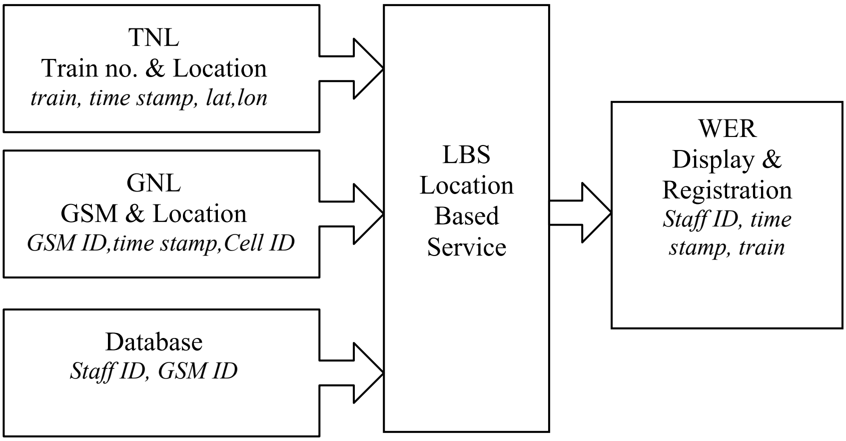

Figure 1: Trial system layout.

collaboration with the software company InTraffic, implemented the system. In five months, the collaborative venture succeeded in developing, testing and assessing a system in practice, in the innovation project. With the system developed, it is possible to reliably determine in real time which train crew members are located in which train.

3 The system

The technical feasibility of the selected suggested solution was tested with the system layout in figure 1.

3.1 Where is the train?

The train position details required for the trial were obtained from ProRail. ProRail collects this information with a network of approximately 10,000 measuring points in the railway network. The measuring points are located approximately 500 metres apart, but there are sections where the separation between the measuring points is considerably larger (never more than approximately 15 km). Because ProRail delivers position data in respect of the railway network, and because LBS (see par. 3.3) has no knowledge of this railway network, a conversion to geographical coordinates was necessary. This is provided by the TNL system.

3.2 Where are the train crew?

Drivers and guards are localised according to the position of their GSM. In this process, use is made of the data from the GSM masts with which the GSM devices have a connection. To be able to receive this information on the LBS platform, an application was developed known as GSM Number and Location (GNL). This application on the GSM sends the current cell ID of the GSM mast to which the crew member's GSM device is connected, at a fixed frequency, to the LBS platform. The frequency with which the messages are sent can be preset. During the trial, the GSM sent a message to the LBS platform every 90 seconds.

3.3 Location Based Services platform

A central element of the trial layout is the LBS system. This system matches train position data with GSM position data. On the generic Location Based Services platform from SmartPosition [3], an algorithm was implemented with this in mind to specify this matching. Because of the specific know-how required for this application (e.g. using cell ID data), it was decided to outsource this task, in this case to SmartPosition. To limit the resultant dependency, an attempt was made to restrict the complexity of the matching functionality and interfacing. With that in mind, alongside the cell ID data, LBS is only supplied with geographical train position data. LBS does not have data about the railway network, timetable or the crew schedule.

3.4 Confrontation with the crew schedule

An interface between LBS and the transport management system to make it possible to confront the matching results with the crew schedule is not part of the trial layout. Instead, a simple display and registration component (WER) was developed, to make it possible to consult the matching results. A component was also developed to make it possible to analyse the matching results (see section 5).

3.5 The matching of GSM and train movements

The localisation of GSMs was restricted to matching with trains or, if that was not possible, pointing out the movement of the GSM at a speed greater than a specified (preset) threshold value. The latter requirement is important to be able to identify the suspected presence in a train, even if it is not possible to specify precisely in which train. This situation can arise if a second train is travelling in the same direction or if train position data are missing because there are no measuring points in the vicinity to detect train passages. Presence anywhere other than in the trains of NSR is not detected.

The matching algorithm was designed to also identify the breaking of a previous match (interpretation: GSM no longer in train), and an extended period of non-confirmation of a previous match (interpretation: train has probably reached its final destination or is stationary, unplanned).

4 The practical trial

Over a period of four weeks, the system was tested in an area in the centre of The Netherlands. The trial area is shown in Figure 2.

Figure 2: Trial area.

Table 1: Distance table for the trial area.

From	To	Distance (km)	Comment
Ermelo	Bilthoven	40	Northeast-Southwest
Bussum Zuid	Lunteren	44	Northwest-East
Bilthoven	Apeldoorn	43	Southwest-Northeast

Amersfoort station is at the centre of the trial area. Table 1 provides an outline idea of the size of the trial area.

The trial area has no relevance whatsoever for the timetable. It matches a so-called traffic controller's area. In other words, the operation of signals and points in this area takes place from a single regional office of ProRail. The trial system was provided only with train position data from this area. For trains passing through the area, the only information provided was position reports from the moment of entry into the area until the moment the train left the area.

Given the central location of the area and the fact that train crew are employed on a range of different routes, a large proportion of the approximately 3300 drivers and 4500 guards employed at NSR regularly pass through this area. However, the trial only involved drivers and guards operating from Amersfoort, one of the approximately 30 crew bases. The application (GNL) was only installed on the GSM responsible for providing GSM position details to LBS, belonging to the participants in the trial.

The trial system was therefore used within this group of drivers and guards for determining on which train they were located, at least in as much as they were on a train at that time travelling through the trial area.

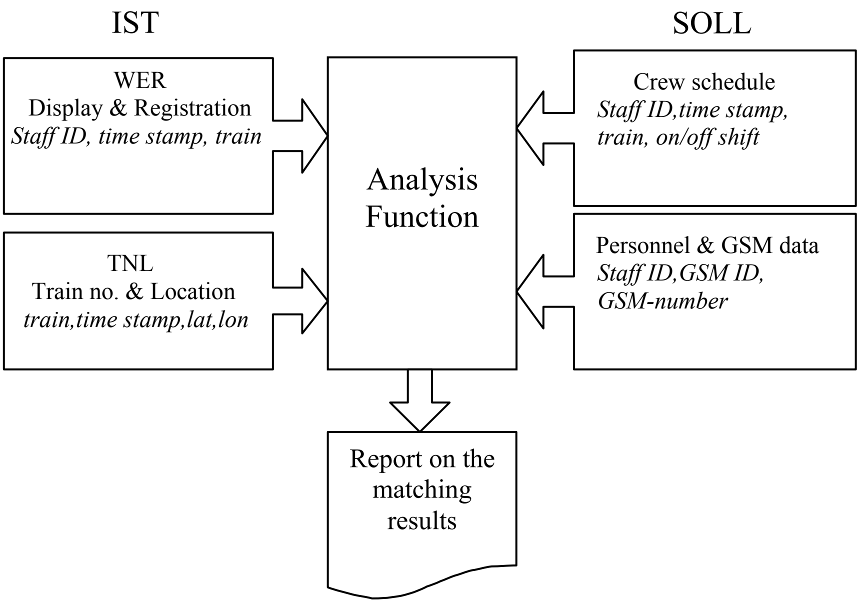

Figure 3: System analysis.

During the execution of the trial, every identified match between GSM number and train number was immediately compared with the transport management system. If a discrepancy was identified, by way of verification, telephone contact was immediately sought with the train crew member in question.

5 The findings

The system was tested for a period of four weeks (May/June 2009).

During the first three weeks, the LBS system was adapted on the basis of errors in the system software and errors in the matches between crew members and train. In addition, it was noted that given a frequency of transmission of GSM position reports of once every 90 seconds, the GSM battery could rapidly become exhausted before the shift (approximately 8.5 hours) ended. The GSM cannot be recharged during the journey. The guard constantly has the GSM in his possession, and needs it to carry out his tasks in the train and on the platform.

For that reason, the trial was subsequently restricted to four hours in any day. Another restriction on use of the GSM device as a source of GSM position data is that the speech communication via the GSM, a common occurrence during disruptions to the train service, hinders the transmission of cell ID data.

After three weeks, the system was considered stable and suitable for implementing extensive testing. In week four, the system was no longer altered, and between 3 June and 7 June 2009, daily trials were held between 12.00 and 16.00 hours. The transmitted matching results for that week are summarised in

Table 2: Number of detected participants per day.

Date	Total
Mon 18 May	104
Tue 19 May	111
Fri 22 May	112
Sat 23 May	95
Sun 24 May	101
Mon 25 May	120
Tue 26 May	111
Wed 27 May	115
Wed 3 June	112
Thur 4 June	114
Fri 5 June	115
Sat 6 June	104
Sun 7 June	105
Average	109

this paragraph. Figure 3 shows the structure of the analysis system. For each match specified by LBS, it was verified whether this matched the crew schedule as laid down in the transport management system.

5.1 Participation in the trial

In total, 218 drivers and guards operating from Amersfoort participated in the trial. During the hours in which the trial system was operational, their presence on trains was detected in the trial area. Table 2 shows the numbers of participants detected on trains over a number of days.

5.2 The reliability of the matching results

During the implementation of the trial, it was assumed that a match recorded by LBS between GSM number (and the corresponding employee according to the administration) and the train number was correct if:

- it matched the crew schedule, or, in the event of a deviation,
- it was confirmed by the driver or guard in question, by verification.

In analysing the matching results, it rapidly emerged that the crew often also travelled by train off shift. The crew often travelled by train from and to their crew base, and also on their days off, crew often travelled by train. If the GSM mobile is then switched on, the system can identify a presence on trains which (it goes without saying) is not reflected in the crew schedule, and which may also not be verified. For such situations, the matching results have been corrected.

Table 3 shows the matching results for a number of selected days. The column with the heading 'number of employees' shows the number of detected

Table 3: Matching results.

Date	Number of employees	Result
26 May	7	100%
27 May	35	100%
3 June	31	97%
4 June	32	100%
5 June	36	97%
6 June	28	96%
7 June	22	100%
Total and average	191	99%

employees (drivers or guards) in the trains. The column with the heading ‘result’ shows the percentage of correctly identified ‘presence of crew members’ in the train.

5.3 Timeliness of the matching

The matching of crew with a train is possible as soon as a train leaves a station located in the trial area (for example Amersfoort) or as soon as a train enters the trial area.

On the basis of 191 measurements, it was calculated that:

a. a 68% matching occurs within 5.5 minutes of departure/entering the trial area
b. a 95% matching occurs within 11 minutes of departure/entering the trial area
c. a 99% matching occurs within 16.5 minutes of departure/entering the trial area

Because of the limited scale of the data set, for a reliability of 95%, an error margin of around 14% is included in the specified times.

For the first case, this means that 5.5 minutes, which equates to 330 seconds, includes an error margin of 47 seconds and for the second case, 11 minutes, an error margin of 94 seconds.

For correction, the above means that 11 minutes following departure of the train (or entry into the trial area), 95% of train crew members has been chartered out, and linked to a train by the trial system.

6 Conclusion

The trial showed that it is possible on the basis of cell ID data and train position data to detect in real time, with an automated system and with a reliability of 99%, in which train crew members are located.

7 Future work

In a system whereby the GSM registers and transmits the cell-ID every 90 seconds during the entire shift of the train crew, it emerged that the load on the GSM battery is unacceptably high. This could perhaps be implemented more intelligently by installing smarter software on the GSM. In addition, speech communication via the GSM, a common occurrence during disruptions to the train service, hinders the transmission of cell-ID data. Further investigations are therefore necessary into possibilities for tackling these problems. One option would be to obtain cell-ID data from telecom providers. Other possibilities include the selective registration and transmission of cell-ID data, specifically only during major disruptions to the train service, by managing the GSM application by means of an SMS broadcast to the train crew.

Meanwhile NSR has started a project which aims to speed up the rescheduling of crew after a disruption has occurred. An important part of this project is the installation of a software module for automatic crew rescheduling. This module will be based upon operations research algorithms (Potthoff et al. [4]). Also for the successful use of such a module, it is important that correct location data of the crew are available. The improvement of those data, including further necessary investigations, will therefore be part of this project.

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