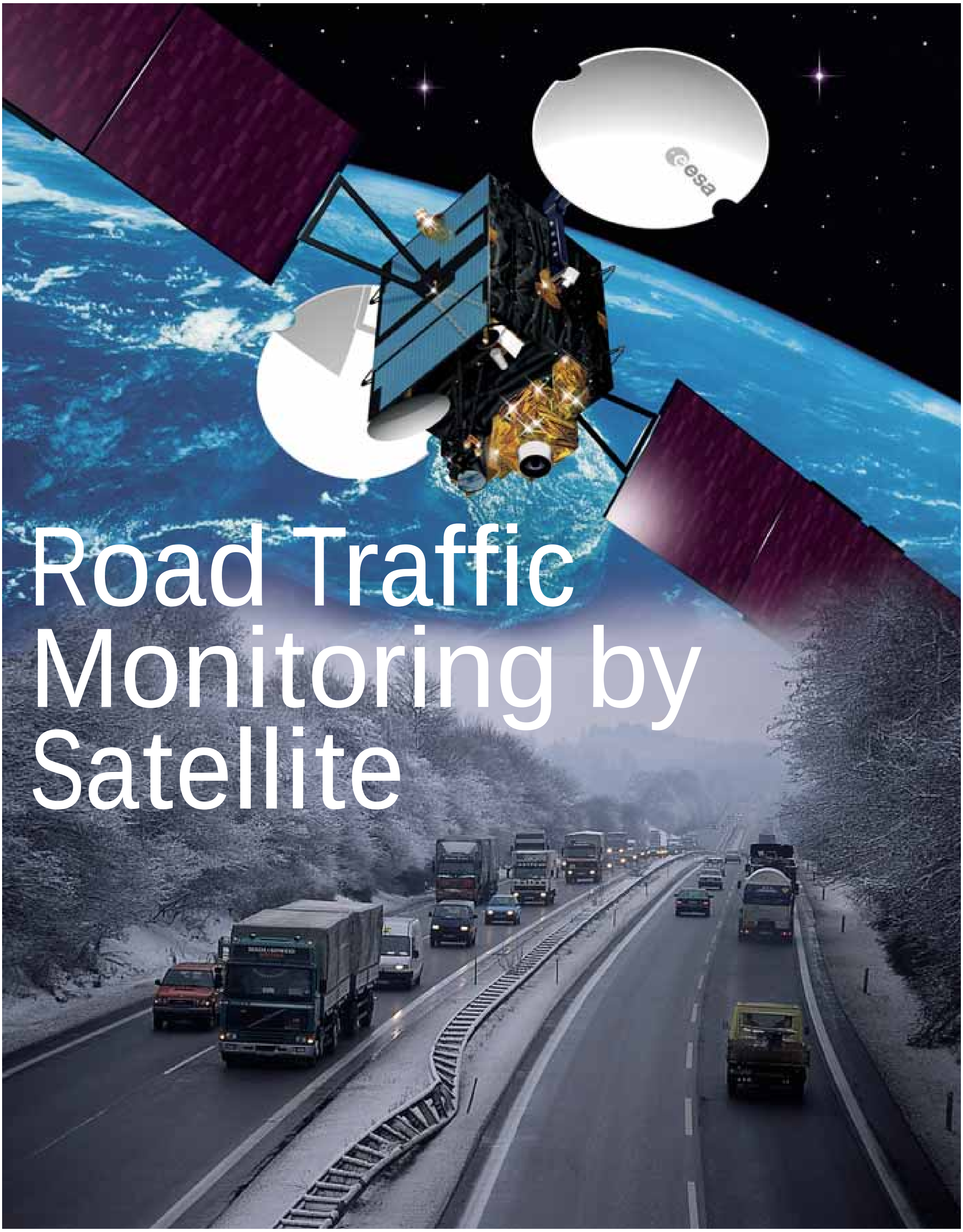

Road Traffic Monitoring by Satellite

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Introduction

Congestion of public road networks is a growing problem in many countries. Authorities are developing initiatives to manage the traffic, but no remedial strategy can be better than the information upon which it has to rely. Consequently, the traffic planners need information that is accurate, reliable, timely and complete. The road users too need good-quality traffic information in order to plan and adjust their routes.

Traffic information has traditionally been collected with inductive-loop detectors embedded in the roads and with video cameras. These fixed installations do not give any traffic information beyond the locations where they are installed, and their coverage is usually confined to congestion-sensitive motorways and a limited number of tunnels, bridges and intersections.

The gathering of ‘floating-car’ data is a totally different concept, whereby a relatively small percentage of the vehicle population generates real-time traffic information just by participating in the traffic flow. The data being collected by the participating vehicles is immediately communicated to a central facility for processing. This approach allows the collection of traffic data across the whole road network – including towns, cities, rural roads and currently unmonitored motorway segments. Floating-car data also has the potential to provide better-quality information. The tracer vehicles can log travel times over a series of road segments, whereas traditional systems measure the traffic only at specific points. In addition, tracer vehicles can detect and report various types of traffic ‘events’ as they occur.

A telecommunications system with wide coverage and operating at affordable cost is vital to the success of the floating-car concept, and the use of a satellite-based system has several advantages over terrestrial means. It provides coverage over large areas, including regions not covered by GSM, GPRS or UMTS. It can also have cost advantages, provided the system design is optimised for the specific nature of floating-car data. There is also the potential to share the in-car equipment and the satellite link with other applications, thereby providing additional cost benefits.

In an earlier project for the Dutch government, ARS Traffic & Transport Technology (ARS T&TT) conducted a successful field trial using GSM technology to collect traffic data from probe-type vehicles. As reported in ESA Bulletin No. 101, Aberdeen University has also studied and simulated the preliminary design of satellite-based floating-car data systems, and the trial reported here builds upon its results. A Road Traffic Monitoring by Satellite (RTMS) project has also been carried out by ARS, and the Technische Universität Dresden (TUD) has contributed to several tasks within the project. The work conducted to date has been financed under ESA’s ARTES-5 programme.

Designing the System

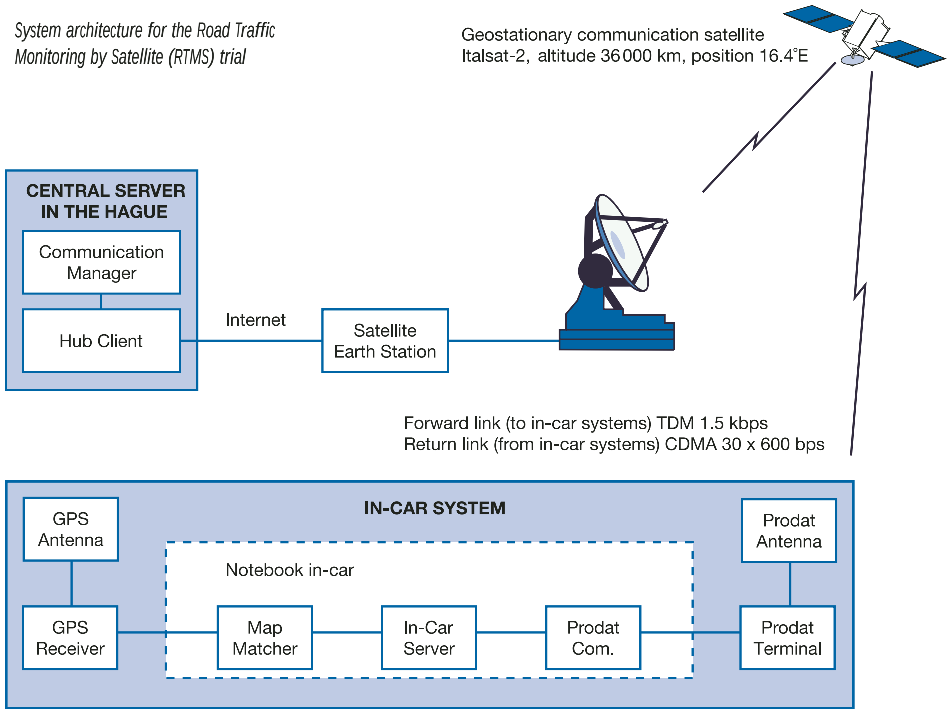
The trial system consists of three parts: an in-car unit, a central computer server and a mobile satellite communication system. The in-car system reads the vehicle's position every second using the Global Positioning System (GPS). An algorithm called the ‘map matcher’ uses that position and a digital road map to determine the vehicle’s speed and to identify the road on which it is being driven. Any traffic congestion is automatically detected for each road segment, based on a priori knowledge of that road, such as the expected speed of traffic under non-congested conditions. If traffic congestion is detected, the in-car system sends a message to the central server. The in-car unit also handles other data flows between the mobile system and the central server, according to the communication protocol selected (see accompanying panel).

On the central server side, an application called the ‘communication manager’ interfaces with the satellite system. It is able to configure the in-vehicle unit remotely, broadcast requests for tracer vehicles, and receive traffic data from the vehicle fleet. For the trial, the server was located at ARS’s premises in The Hague. It interfaced with the Telespazio Earth station in Lario, Italy, via the Internet. Lario was the access station to the L-band payload of the Italsat F2 satellite that was used for the trial.

In a full operational system, the central server would also connect with external service providers, such as a Traffic Information Centre and possibly providers of ancillary services such as locator services, emergency and breakdown call centres, and fleet-operation centres.

The mobile satellite communication system used for the trial was Prodat-2, developed 10 years ago by ESA as a technology demonstrator. It has been used in the meantime for many trials and demonstrations. For the RMTS trials it was operated on a good-will basis with the help of Telespazio (I) and the contractors involved in its design.

System architecture for the Road Traffic Monitoring by Satellite (RTMS) trial



Conducting the Field Trial

The three-month field trial, from April to July 2002, was intended to validate the RTMS concept by means of a pilot implementation, focusing on two aspects:

– technical performance: the ability to communicate effectively in various environments, and
– traffic-monitoring performance: the effectiveness of the system in detecting traffic congestion and determining traffic speeds.

During the trial, a small fleet of vehicles continuously recorded their positions, assessed the traffic situation and sent their findings to the central monitoring system. The fleet consisted of five postal trucks, eight container trucks, two sewer-cleaning trucks and a passenger car, all of which were operated intensively on weekdays in the Rotterdam-Rijnmond area of the Netherlands. The in-vehicle systems were installed on notebook computers and required no intervention on the part of the drivers. They were configured to log raw data for later analysis, including the GPS positional data and vehicle-satellite communication status every second. This allowed replays of completed trips for analysis and optimisation of the algorithms. A relational database and viewing tools were developed for analysis, demonstration and optimisation, and the filtering out of invalid or less useful data.

What the Field Trial Showed

With the Prodat-2 system, the hub station transmits a continuous carrier signal towards the mobiles (the so-called ‘forward link’), and each mobile records the quality of its reception every second. The availability of the forward link is therefore easily computed for any given time interval, and can be plotted on a map. The quality of the return link is not so easily measured because no continuous transmission takes place. However, the quality of the forward and return links is highly correlated: either there is a clear view, or the signal is partially blocked by some obstacle and is unusable. On a longer time scale, the return link’s quality can also be assessed by statistical recording of the success/failure of message transmission, and the number of attempts required for successful transmission.

In the densely populated and industrialised area between The Hague and Rotterdam, for example, both the return and forward links were found to be present during 96% of the time. Considering the particularly difficult, mainly urban, propagation environment, this was a remarkably good result. During the field trial as a whole, only 7% of the messages required retransmission, but in most cases several attempts were needed before success was achieved.

In terms of performance in different environments, satellites provide line-of-sight communication and so performance can be expected to be good in open areas, and to degrade when more and more obstacles are encountered in urban environments. This expectation was confirmed by the RTMS trial in that communication was best in rural, suburban and industrial areas, was somewhat degraded in areas with complex fly-overs and bridges, and was poorest in downtown areas with large concentrations of high buildings. Even in the downtown areas, however, communication remained intact for about 80% of the time.

The map matcher is a vital element in the detection of traffic data. If the vehicle's position is not properly matched to the road map, the vehicle's calculated speed and hence the 'normal speed' for the particular road segment on which it is traveling will be unreliable. The system's performance was therefore assessed by manually comparing a selection of map-matcher results against the actual itineraries. The results were very good, with 94% of each trip accurately matched, and there are reasons to expect that further improvements might be possible.

The ability to detect traffic congestion was assessed by manually comparing a selection of the traffic alarms generated automatically by the system against the real situation. A number of false alarms were generated during the tests for various reasons, but the nature of these false detections indicates that again improvement is possible by refining the algorithm and/or improving the map and the normative speeds.

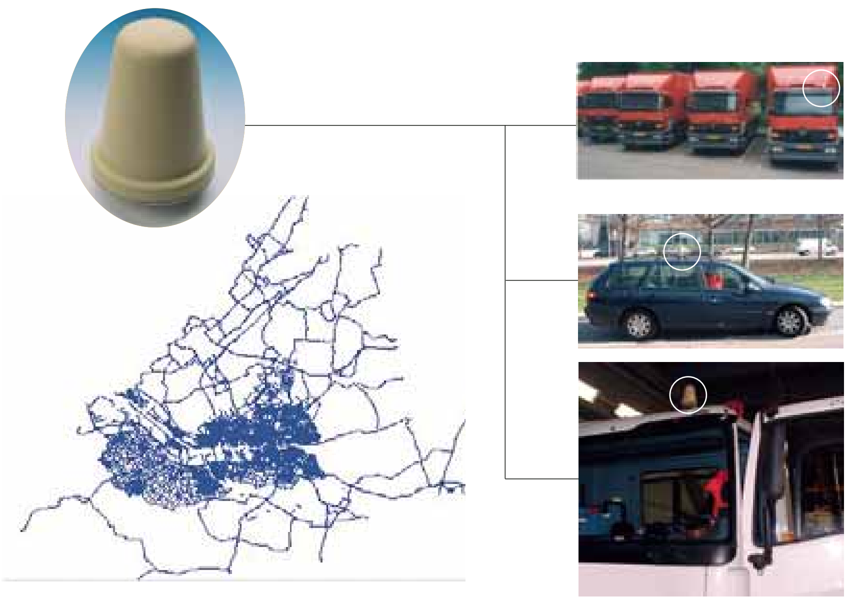
Choosing the Communication Protocol

As an RTMS system will ultimately provide data for existing Traffic Information Centres (TICs), its data format should preferably be based on an existing standard. A survey of today's traffic-information protocols led to the choice of the GATS standard (Global Automotive Telematics Standard), developed for cell-phone SMS communication, as the baseline. An adapted GATS protocol was therefore designed to allow the selection of relevant information elements and optimisation of the length and coding of individual information elements.

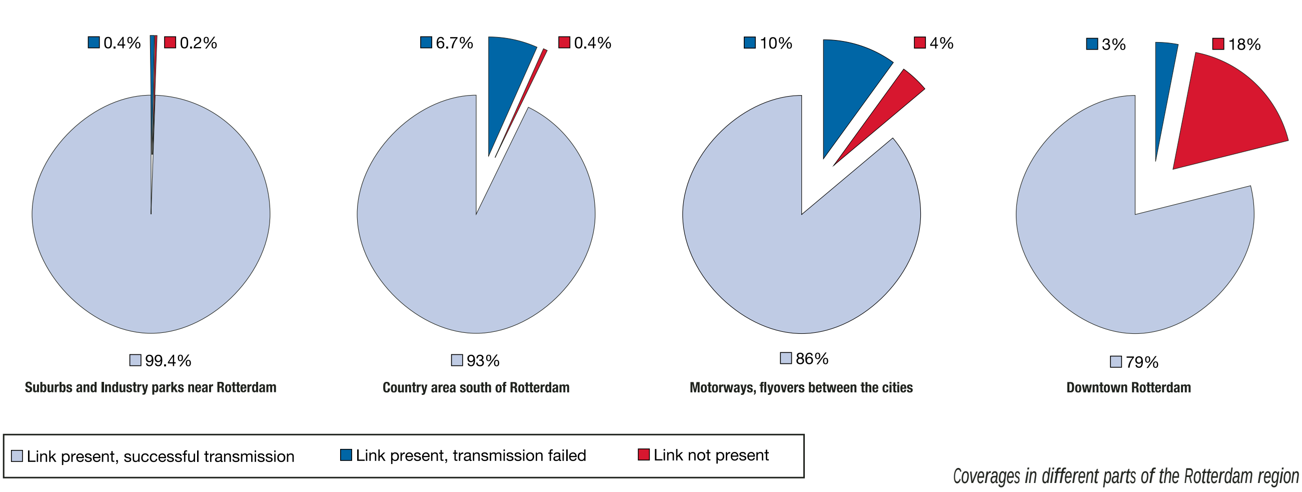
When many mobile units share a communication channel to a central station, a discipline has to be established for efficient sharing of that channel. In line with the Aberdeen study, three possible access schemes were investigated:

– Random-access mode (event driven): the vehicle transmits data about traffic events whenever they occur. The advantage is that transmission only takes place when an event of interest occurs. The drawback is the risk of collision of transmissions from different mobiles, reducing the effective capacity of the communication channel.
– Polled random-access mode (TIC driven): a subset of vehicles are invited to transmit if they meet certain conditions. For example, vehicles within a defined geographical region that are not already participating in data collection may be invited to join the system. The potential size of the addressed community must be adapted dynamically to avoid congesting or starving the channel.
– Addressed poll mode (fully coordinated access): the central system rigidly controls access by sending regular requests for information to specific vehicles, which return their replies in a specified time slot. This mode is collision-free, but involves complex management in deciding which vehicles to poll in order to make optimum use of the limited communication capacity available.

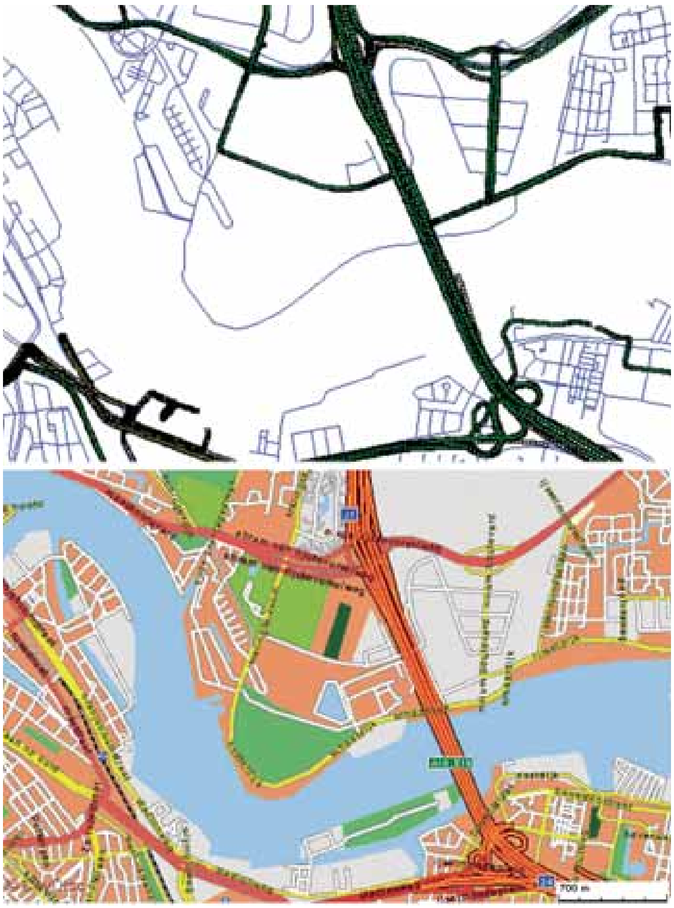
The RTMS trial implemented only one mode: return-link random-access event reporting in combination with forward-link broadcasting. This choice was driven by the access modes available with the unmodified Prodat-2 equipment. It was quite appropriate for a communication trial of this size, where system capacity was not an issue, and message collisions rare. For a full-size operational system, however, a combination of random and addressed polling should be considered, possibly augmented by random-access reporting of high-value events. Optimisation of when to use which mode, in order to balance the channel loading inefficiency inherent in random access against the inefficiency resulting from the addressed poll mode sometimes carrying data of less interest to the TIC, then becomes one of the design challenges.



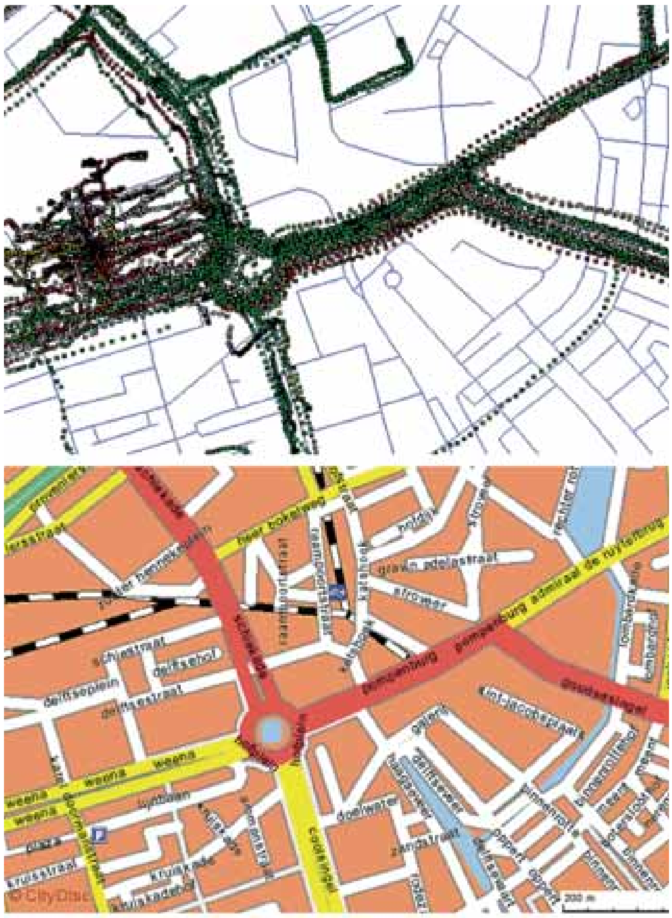
Area of focus (left) and fleets (right) for the field trial



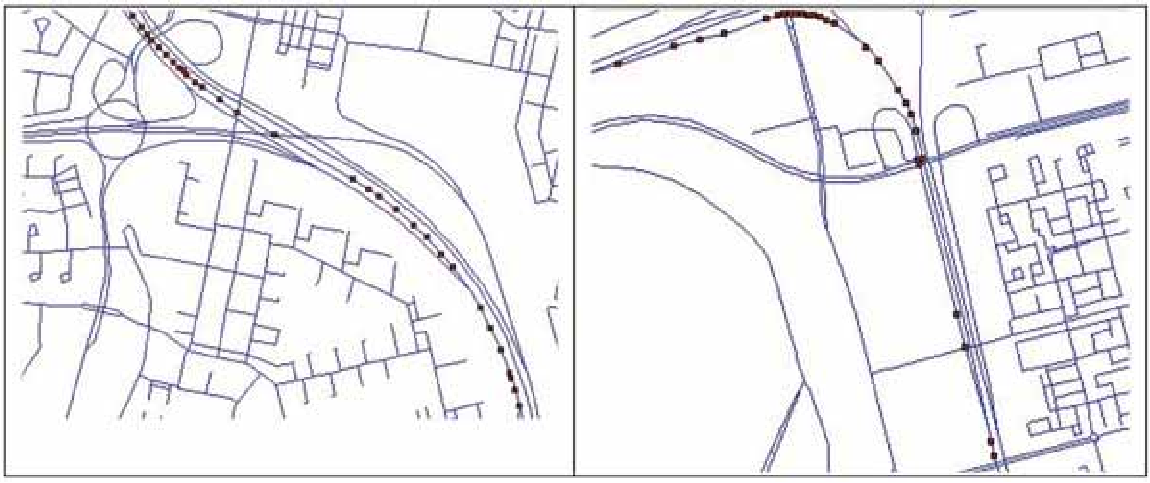
Coverages in different parts of the Rotterdam region



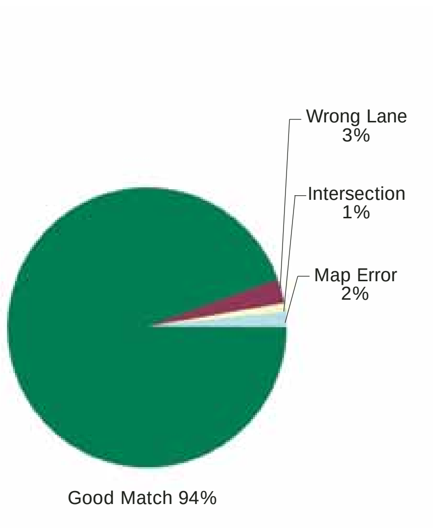
Communication performance in a relatively open suburban area surrounding the A16 motorway in Rotterdam, near the Brienenoordbrug bridge. Green dots indicate good-quality communication, while other colours indicate various degrees of loss of communication



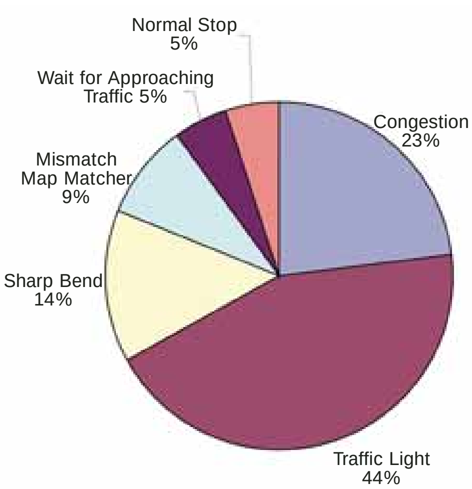
Communication coverage in the downtown area of Rotterdam with its many tall buildings is relatively poor, but the effect is very localised and disappears within 50 to 100 metres. The satellite being accessed is almost directly south, so north-south roads perform better that east-west roads



Examples of a good map match (left) and a failed match (right) in a complex motorway situation where the vehicle is erroneously located in the exit lane rather than in a motorway lane



Accuracy of the Map Matcher



Traffic events generated during the three-month field trial

The Road Ahead

At the time of writing, several issues must still be resolved to pave the way towards an economical full-scale implementation of RTMS:

– The costs of equipment and service must be brought to an acceptable level. If the equipment and operations can be shared with other valuable services, such as fleet management, emergency services, route guidance, etc., RTMS can certainly be economically viable.
– The 10-year-old Prodat-2 terminals used in the trial were heavy, bulky and power-hungry. With today's technology, small, lightweight terminals with low power consumptions are fully feasible, being in essence no more complex than a GSM phone. Economy of scale is essential.
– The RTMS trial used an available system and its equipment, and was thus somewhat constrained by that system’s capabilities. A future operational system should be based on a design specifically optimised for RTMS functionality, for which some research results that already exist in the Aberdeen study can serve as a basis.
– Compatibility and/or interoperability with present and emerging standards for data formats is essential for smooth integration into the in-car environment.
– Further R&D is needed to optimise the behaviour of the detection algorithms. Specific situations like traffic lights, bends and stops must be dealt with and the map optimized accordingly.
– Due to the small scale of the trial, the anonymity of the participating vehicles was not given much attention. For an operational system, however, this is of paramount importance and the Aberdeen study suggests ways to achieve it. If the in-car equipment supports both RTMS and other services, it may need to have an anonymous identity for the RTMS and a known identity for the others. These dual identities must then be kept strictly separate.

Conclusions

The RTMS project has shown that the collection of valid and valuable traffic information by means of satellite is feasible from a technical point of view, even in built-up areas. RTMS will enable road authorities to cover the whole road network - not just the bottlenecks - without huge investments in infrastructure such as loop detectors, video detectors and the corresponding cabling. For drivers, it will lead to better information, particularly if combined with in-car route planners and navigation systems. Traffic information and advice can be broadcast by the RTMS system itself.

In the near future, a host of new applications and services can be expected to emerge for in-car usage. They will be provided and promoted by accessory and car manufacturers, and service, software and telecommunications providers. RTMS lends itself well to incorporation into such an in-car infrastructure.