The Matrix
A Tolling Revolution?

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Despite its recent successes, satellite-based technology is still not widely accepted as the preferred option for tolling. Only recently, a European government with a road network suitable for satellite-based tolling opted for standard tolling technology instead.

Decisions like these demonstrate that there is little recognition of the fact that the first satellite-based tolling system for motorways – the German system – has been working smoothly since it started operating. More over since that early system, the feasibility, robustness and reliability of Global Navigation Satellite Systems (GNSS) technology have been proven many more times.

A technically feasible roadmap for future GNSS-based tolling systems has become apparent during recent field trials conducted in Australia by Transurban, Telstra and Siemens Tolling Technologies.

**FUTURE REQUIREMENTS**

Siemens Tolling Technologies believes that tolling systems will converge with regard to their scope and their technologies. As a result, urban and interurban tolling systems will merge and culminate in nationwide road-user charging schemes.

Consequently, the focus will be on combining segment-based with distance-based tolling – to measure the overall distance driven – and area-based tolls for cities or defined zones. It will then become necessary to integrate the various existing schemes into one GNSS tolling system.

In mid-2005 an alliance was formed with Transurban, Australia’s market leader in toll road operations. It consisted of Telstra, which was responsible for GSM/GPRS carriage and the provision of digital mapping software; several sub-contractors, including ARRB, a leading Australian consulting company in the ITS environment that was responsible for the test specifications, evaluation and analyses; and Siemens Tolling Technologies, which was the solution provider of the GNSS application and systems integrator.

The field trial – dubbed ‘Matrix’ – was conducted from November 2005 until the end of February 2006 in Australia.

The main goals of this field trial were to better understand the maturity of the Siemens GNSS tolling technology; the practicality of centralized versus decentralized approaches to tolling, and whether GNSS tolling could facilitate a smooth transition from existing systems to this pace-making technology.

The locations for the tests were Melbourne (‘Victoria urban’), a defined cordon in Sydney (‘New South Wales urban’) and a road north of Sydney (‘New South Wales regional’).

The trial was set up to achieve reliable results. Besides the existing e-TAG® device for Australia’s toll roads, a GPS reference receiver and a Siemens hybrid OBU 1372 were mounted inside each participating vehicle. The latter OBU contained a GPS receiver and a DSRC 5.8 GHz microwave module.

In parallel, a ‘quality monitoring station’ constantly checked the availability and quality of GPS satellite constellations during the field testing. The technical back office was in Vienna, which hosted the GNSS tolling solution and was responsible for trip reconstruction based on passage data from the OBUs in the field. All participating parties had direct access to the necessary data from anywhere in the world via a secure web interface.

**VICTORIA URBAN**

The solution was first tested on Melbourne’s CityLink, which is one of the best known DSRC microwave, Multi-lane Freeflow (MLFF) toll roads in the world. Key questions that were addressed during these early trials were: How accurate is the recognition rate for the GNSS segments? Does centralized or decentralized tolling perform better? Is the hybrid OBU able to detect the existing microwave gantries? Is it therefore possible to migrate slowly, step by step, from the existing technology to GNSS?
The result was a 99.74 percent overall recognition rate collected in over 500 trips and more than 6,900 passages recorded. This was a welcome, positive surprise for everyone involved. The existing microwave gantries on CityLink have been detected but not integrated into the tolling application as systems integration was not part of the trial.

The participating vehicles received signals from six or more satellites throughout their trips. The GPS receivers were subjected to robust tamper testing as part of the trialing. For example, the GPS receiver was switched off at defined locations for different time intervals. If the time interval lasted only a few seconds, the missing segment could be recalculated. If the time interval lasted more than 10 seconds, an alarm record was generated, stored and sent via GPRS to the back office.

This alarm record could then serve the toll road operator in two ways. First, it showed that at certain places and times problems had occurred with GPS reception, and second, as it monitored every vehicle passage, it was also very informative. It logged whether the alarm records were being generated by the majority of vehicles or whether it was a single occurrence. The records therefore served as a means of enforcement in parallel.

Before being released for trial in the field, the Siemens OBUs were subjected to rigorous laboratory testing by a qualified, independent testing authority to ensure they met a range of quality standards for use in normal commercial tolling environments. The quality monitoring stations monitored GPS satellite availability throughout the length of the trial and simulated optimal results, which could be compared with observations in the field.

NEW SOUTH WALES URBAN

The traffic situation in Sydney differs from that in Melbourne. Due to its geographical location, vehicle use patterns and physical environment, Sydney suffers more heavily from peak hour congestion than Melbourne. It therefore provides an appropriate testbed for assessing the different capabilities of the GNSS solution.

The tolling application was to be tested in Sydney’s urban environment. Therefore a cor-don was created, which then had to be detected. The goal was to assess whether the tolling application could correctly detect a certain class of vehicle when it entered the cordon and make an immediate notification to the back office. Furthermore, trips alongside the cordon had to be detected reliably and correctly.

This part of the trial also gave satisfactory results. In order to detect the different virtual toll points along the cordon, trips were made in clockwise and counter-clockwise directions. As before, the tolling application outscored the normal requirements for such systems. The overall recognition rate was 99.14 percent, which indicated that it is feasible to correctly detect and monitor the entry and exit of vehicles into the satellite-based urban cordon.
Recently, digital maps have become so reliable and commonplace that it was also possible to plan and work out the whole second part of the toll trial from the Siemens office in Vienna. Some adjustments were still necessary, but since Siemens’ Seattle trial, enormous progress has been made in the development of efficient and accurate geocoding techniques.

A further – and possibly specifically Australian – requirement was implemented by Siemens. While the OBU received, detected and collected position data, the quality and strength of GSM reception was also recorded.

GSM signal strength and coverage turned out to be better than satisfactory. The OBU showed it was capable of buffering position data for more than 20 hours without transferring them – even if the data is collected every second. When the connection is re-established the stored data is then transferred to the back office reliably.

‘FAT’ VERSUS ‘THIN’

Within the GNSS community there is much discussion over which is the better approach: The ‘fat client’ model, which accommodates less data volume and is relatively complex to operate (this system is the basis of the successful German tolling system) or the ‘thin client’ model, where position data is collected and transferred to the back office where it is processed. During the Matrix trial, the Siemens OBU could be switched between the two modes. The trial demonstrated that both approaches are suitable and offer the same performance.

The benefits of each model should be considered on a case-by-case basis depending on the project. But some arguments for the thin client model would include that it is less complex to operate, easier and cheaper to maintain, and offers a better platform for the provision of value-added services.

SATELLITE-BASED TOLLING

The Matrix trial has proven that a satellite-based tolling application can work smoothly and reliably, with extraordinarily good recognition rates. Furthermore, it demonstrated the possibility of migrating existing tolling technology slowly and efficiently with the help of hybrid OBUs. This provides the possibility of thoroughly implementing or testing already existing or upcoming value-added services.

The Siemens tolling application can be utilized for more than tolling. It can also be used for the correct detection of special vehicle classes, subject to restrictions on the load they carry (such as hazardous goods vehicles).

The reliability of the technology is now proven. For those who have to make a decision as to whether to implement it, this technically excellent and mature solution is available to serve their needs.