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TRAPRIO

"Traffic Priority in City Traffic"

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Rising traffic congestion all over the world calls for new Intelligent Traffic Systems that can improve public transport and vital services such as emergency vehicle operations. Within the TRAPRIO project funded by EUREKA, TSS is doing just that with a system for:

- Traffic Light Priority
- Passenger Information

The TRAPRIO system has been implemented in the cities of Kolding, DK and Devon and Maidstone, UK.

Objectives
The objective with the TRAPRIO project is to create an improved emergency services in order to create:
- Lower response time
- Eliminate dangerous passing of red lights
- Provide warnings to hospitals of arriving ambulances,

and to create a increased passenger satisfaction with improved public bus services in order to:
- Decrease delays
- Enable faster routes
- Provide information to passengers

Giving green light to ambulances, fire fighters and other emergency vehicles allows these to pass through a city faster, cutting the response time with vital minutes. Ensuring green light further put an end to emergency vehicles' highly risky passing of red light, the cause of many accidents every year. The TRAPRIO concept can also be utilised to provide hospitals with an automatic warning when an emergency vehicle is approaching.

Giving green light to buses when these are late can cut delays in bus services and thereby improve passenger satisfaction. Going one step further and always give green light to buses can be used to cut journey time – making public transport a more attractive alternative to private transport. Another important factor in passenger satisfaction is accurate real-time information about arrival and departure times – onboard buses, at bus stops and via other media like the Internet.

Method
To meet the objectives in the TRAPRIO project TSS has developed a cost-effective and reliable system for Automatic Vehicle Location (AVL) – the central part of Traffic Light Priority and Passenger Information Systems.

The AVL system is powerful and distinct in itself with the fact that the equipment installed in the infrastructure can be utilised by any vehicle and used for a broad range of Intelligent Traffic Systems like:

- Traffic Light Priority
- Passenger Information
- Terminal Management
- Fleet Management
- Hospital Warning
- Access Control

TSS Automatic Vehicle Location (AVL) System used in TRAPRIO

The Automatic Vehicle Location (AVL) system used in the TRAPRIO project is based on the use of low frequency RFID battery-less tag embedded in the infrastructure and onboard tag reading equipment. The AVL system provides real-time position data with accuracy below 1 meter at speeds up to 180 km/h.

This naturally means that the AVL system can be used by both public and private buses, emergency, utility and any other type of vehicle for a broad range of applications.

The basis in the TRAPRIO system is the battery-less TSS PositionTags and the TSS RF-ActiveAntenna. The PositionTags are embedded at strategic locations throughout the infrastructure, e.g. at traffic intersections and bus stops and the ActiveAntenna is mounted underneath the vehicles as seen in figure 1.

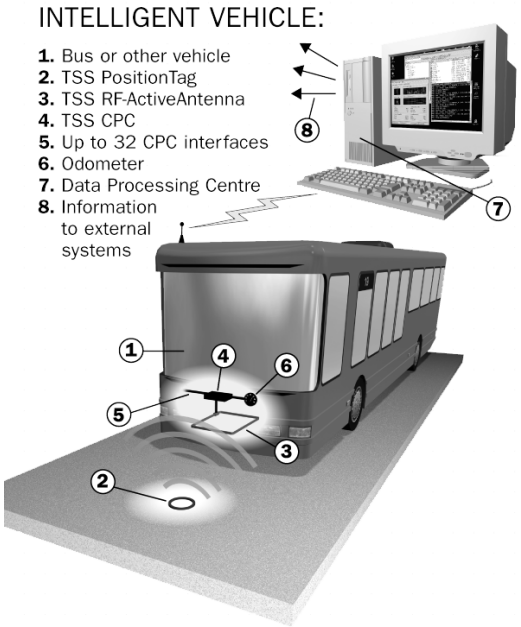

Figure 1. The TSS TRAPRIO AVL system

The functionality of the system is the following. The ActiveAntenna powers up the PositionTags and read the unique ID codes stored in the tag memory, when passing a tag location. The unique PositionTag ID codes refer to position information stored in a database, giving the position and direction of the vehicle with accuracy better than 1 meter.

In-between tag locations, vehicle position data is derived from odometer readings related to the latest tag location. Position data derived when passing over PositionTags is used to calibrate the odometer, increasing the position accuracy derived from odometer readings. Odometer readings are also used to provide vehicle speed data.

The onboard positioning equipment and sensors are connected to a System Interface, a small computer that handle communication between all the various onboard equipment and the Traffic Control Centre. The System Interface transmits vehicle ID code, PositionTag ID codes, Odometer readings, and other data together with a time stamp to a central computer in the Traffic Control Centre via the radio system.

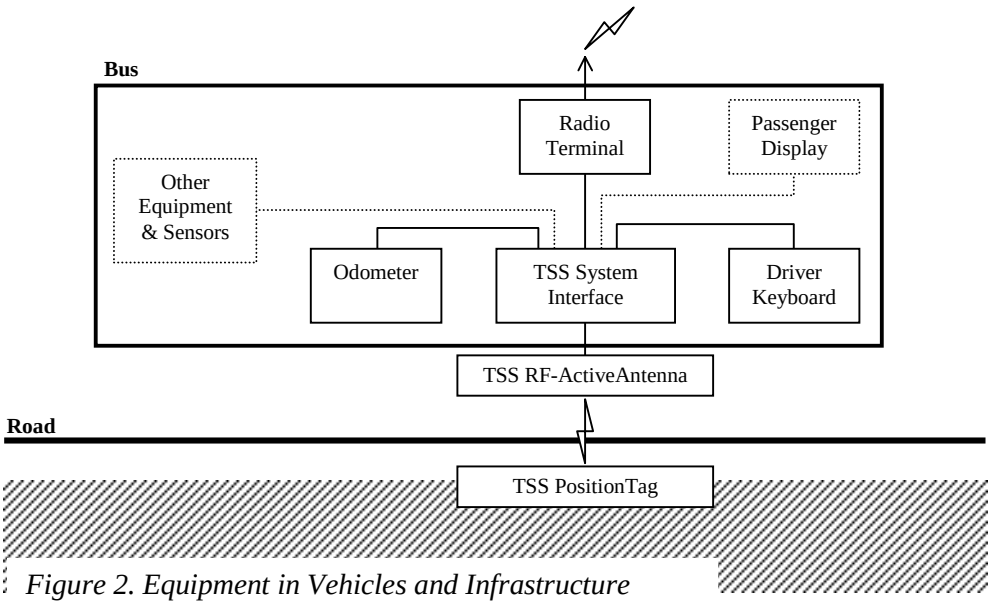

Figure 2. Equipment in Vehicles and Infrastructure

In the Traffic Control Centre the data received from the vehicles is processed in order to derive accurate vehicle position, other information and actions related to the relevant application, e.g. priority request, information display changes, driver performance, etc.

PositionTag:
The PositionTag contains a 64 bit read-only memory with a unique ID code. The tags are battery-less, induced with power to transmit by the magnetic field from the RF-ActiveAntenna. The tags are as such practically maintenance free and can hence be embedded in the road surface. Operating in 125 kHz the tags are able to communicate through the surface with the RF-ActiveAntenna when this passes.

The tags are embedded in depths of 5-7 cm, protecting it against resurfacing work. To embed tags a ring is cast in the road surface using a milling head. The tag is placed in the ring and sealed with hot asphalt or other material. The process of embedding tags takes 5-8 min and can be done with minimal interference to the traffic and the road surface. At PositionTag locations tags are embedded in a matrix structure in order to insure that a passing vehicle reads one of the tags.

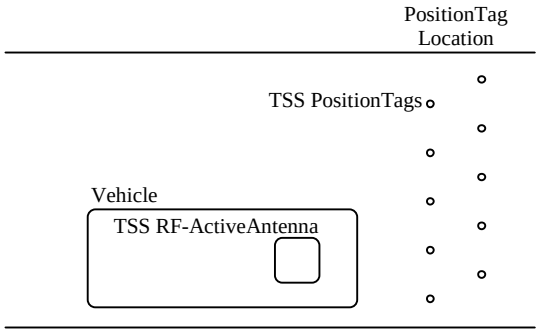

Figure 3.Position Tag location.

TSS RF-ActiveAntenna:
The RF-ActiveAntenna is a combined RF-Antenna and RF-Controller unit operating in 125 kHz. The standard size for vehicles is 100x50 cm. Fitted with a RF-ActiveAntenna a vehicle can pass a PositionTag and read the PositionTag ID code at speeds up to 180 km/h. The RF-ActiveAntenna contains a programmable ID code, identifying the vehicle.

The RF-ActiveAntenna is installed underneath the vehicles and connected to a System Interface via a cable and RS-422 interface. 12 VDC 0.5 A power must be supplied from the vehicle battery through the same cable.

TSS System Interface:
All onboard equipment is connected to a System Interface. This is in the project TRAPRIO a PC based unit. The System Interface controls the chosen radio terminal and modulates up to the relevant transmission protocol used by the chosen radio network system.

Odometer:
Odometer signals are used to measure the distance travelled from a PositionTag location, securing continuous position data at any point in the infrastructure.

Radio Terminal and Radio Network System:
In TRAPRIO a trunk radio network system is used based on the use of the Aloha protocol.

Driver Keyboard:
Driver Keyboard is used to add route or schedule number information to the system, enhancing the information level.

Data Generation

Onboard generated data:

Data:	**Data source:**
Vehicle ID code	Programmable ID code stored in the RF-ActiveAntenna.
PositionTag ID code	Read by the RF-ActiveAntenna.
Odometer Signals	Pulse from an odometer connected to the System Interface or directly to the RF-ActiveAntenna.
Vehicle Speed	Based on calibrated odometer readings.
Time Stamp	Internal clock in the RF-ActiveAntenna.
Route or Schedule Number	Manually entered by the driver on alphanumeric keyboard.
Other Data (optional)	Various onboard equipment and sensors connected to the System Interface.

Traffic Control Centre calculated vehicle data:

Data:	**Data source:**
Vehicle Position	Calculated on the basis of PositionTag ID codes, a database containing all relevant PositionTag locations and calibrated odometer readings.
Driving Direction	Calculated on the basis of PositionTag ID codes and a database containing all relevant PositionTag locations.
Error Messages in case of missing PositionTag	Derived by comparing odometer readings with database information about tag locations.

The TRAPRIO Traffic Control Centre

In order for the TRAPRIO project to work a Traffic Information & Priority System is used at Traffic Control Centre (TCC) level. The TCC is in the TRAPRIO project based at the various existing traffic control centres at the municipalities.

The Traffic Information & Priority System consist of two pieces of software namely the Navigation Chart and Event Tracker software.

Navigation Chart:

A database with all relevant static information concerning PositionTag ID Codes, PositionTag Locations, Traffic Light Intersections, Traffic Light Controllers (TLC), Bus Stops, etc., as well as dynamic information concerning Vehicles, Time Schedules, Priority Rules and Activation Commands.

Event Tracker:

A program module that handles all incoming data from the vehicles; Calculates vehicle data such as position, driving direction and speed; Request actions for Traffic Light Priority, Passenger Information, Driver Information and any other actions included in the system; Route selected vehicle data to other parties such as hospitals and fleet operators.

Within the TRAPRIO project Traffic Light Priority can either be given directly from the Traffic Information & Priority System to the Traffic Light Controllers (TLC) as in Kolding and Exeter, or via the existing Urban Traffic Control (UTC) system as in Maidstone.

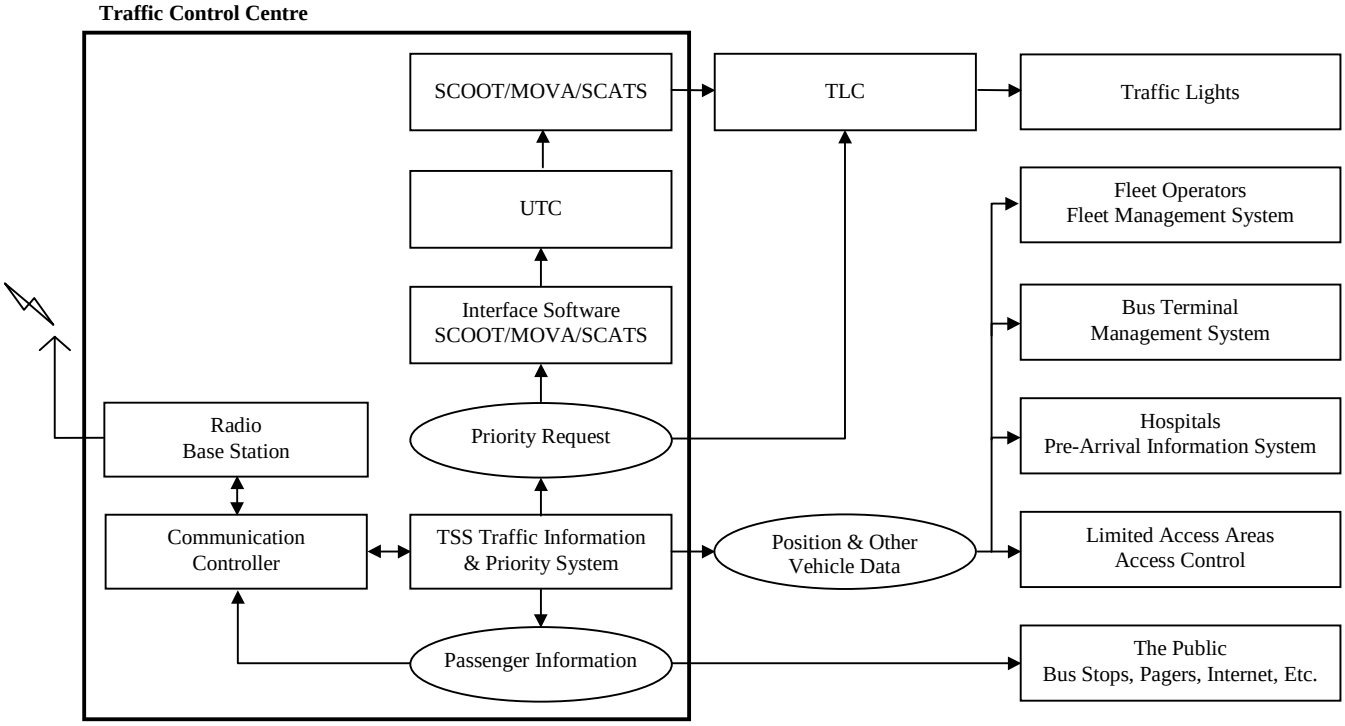

Figure 4. Information flows within the TRAPRIO project.

Creation of a pre-emption/traffic light priority
Giving green light to buses when these are late can drastically cut delays and journey times in bus services and thereby improve passenger satisfaction.

For ambulances, fire trucks and other emergency vehicles traffic light priority allows these to pass through a city faster, cutting response time with vital minutes. It further puts an end to emergency vehicles' highly risky passing of red light, the cause of many accidents.

Other vehicles like money transfers and utility vehicles can also benefit from traffic light priority. Money transfers will have a lower risk of being robbed as they stop fewer times during the journey. Granting green light to utility vehicles, e.g. in the early mornings, would insure that these are cleared away from the traffic as early as possible.

The TRAPRIO system is designed to create a traffic light priority. Within TRAPRIO PositionTag locations are established before the traffic light intersections. When a bus or other vehicle included in the system passes a tag location, the Traffic Information & Priority (TIP) System decides if the vehicle should be given priority, based on a priority algorithm stored in the system. If priority is granted the system sends a request for green light to the existing UTC or directly to the Traffic Light Controller (TLC).

A key issue in the TRAPRIO system is to minimise the time a green light is given to a vehicle, so that the traffic light can return to its normal cycle as fast as possible. If green light is granted for too long time, this not only obstruct the general traffic, it can also make waiting drivers ignore the red light in believe that something has broken down– potentially creating a dangerous situation if for example an emergency vehicle is on its way to pass through the intersection.

The TRAPRIO system therefore continuously monitors the vehicle's approach towards the traffic light intersection, calculating expected time of arrival based on odometer readings. This way request for priority can be given dynamically at the latest necessary moment and changed if necessary, taking into account if the vehicle speeds up, slows down or stops completely, eliminating the problem of unnecessary or wrong requests that could otherwise obstruct the general traffic. Monitoring the vehicle's approach using odometer is also used to return the traffic lights to normal as soon as the vehicle has passed the intersection.

In areas where special bus lanes and early bus-only traffic light exist, it is possible to insure that the early bus-only traffic light is used only if a bus is present at the intersection. Placing PositionTags in the bus lane just before the traffic light intersection does this. When a bus passes over this tag location a request for early bus-only green light can be send to the traffic light control system, allowing the bus to move forward before the remaining traffic. Controlling early bus-only traffic lights this way insures that the general traffic flow is only obstructed when necessary.

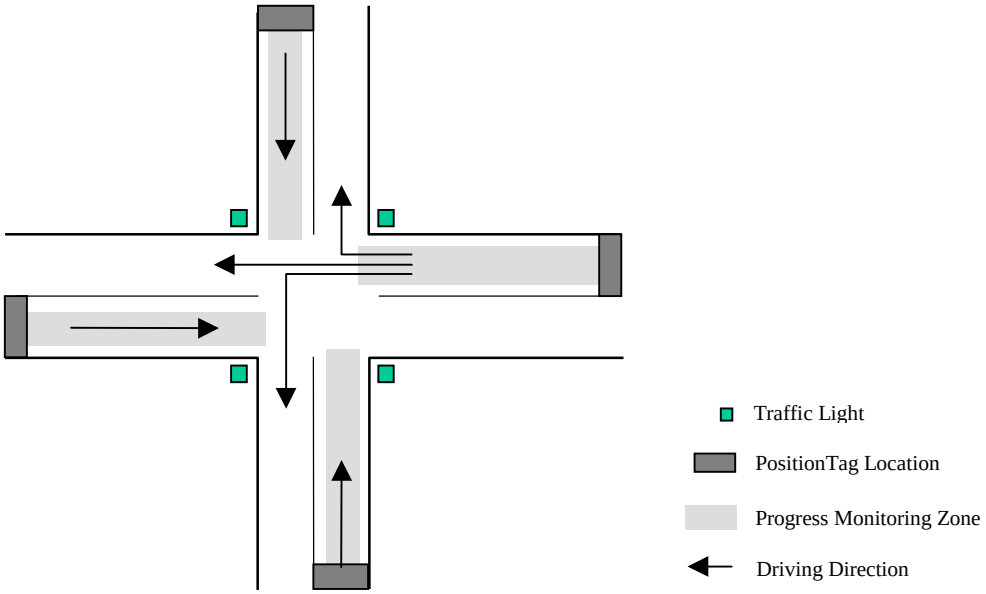

Figure 5. Monitoring of the vehicles progress towards the intersection

Priority algorithm:
Within the TRAPRIO project a priority algorithm has been developed according to the specific application requirements. For the buses the algorithm is related to the timetable, only granting buses behind schedule green light. Emergency vehicles get priority only if the emergency lights are turned on. It is within the application possible to have individual priority algorithm for different traffic light intersections at different hours of the day.

The algorithm also specifies priority in cases of two opposite requests at one traffic light intersection. This does not depend on a "first-request-first-serve" basis, but take the specific vehicle into account, e.g. giving emergency vehicles higher priority than buses and priority buses higher priority than other buses.

Preliminary Evaluation results
The TRAPRIO project has been ongoing for two years. The first phases of the project was used to develop the concept. During the first phase of the project all development tests was carried out on single buses and intersections in both Denmark and the UK. During the second phase of the project that has been ongoing for approx. 1 year the implementation of 13 buses and two fire trucks and two ambulances and 29 intersections has been finalised in the three participating cities.

The evaluation period has just begun in the project and only the preliminary results and the expectations can therefore be given. The preliminary results and expectations have been found on the basis of general surveys and interviews mainly with the users of the TRAPRIO system.

The presentation of the first evaluation results and the expectations is made for the following groups: the public, emergency operations, local authorities and fleet operators:

The Public:

- The TRAPRIO project seems to create a faster and more reliable bus services. The expected results are that delays will be decreased by 50-70%.
- The TRAPRIO project seems to create a better bus travel comfort based on a smoother driving.

Emergency Operations:

- Faster and safer response time for emergency vehicles, it is expected that the emergency response time can be decreased by 5-10%.
- Less stressful and better comfort for drivers since red light crossings is avoided and a smoother driving is possible.
- They expect a lower accident rate, which only can be measured over a large number of years.
- They highly appreciate the possibility to have a automatic registration of the emergency vehicle response time.

Local Authorities:

- They expect that the TRAPRIO system can create a more attractive bus service to the public and thereby provide a better alternative to private commuting
- They expect that the bus schedule planing will be highly improved since they on the basis of the TRAPRIO system have accurate historic data
- Since they have real time positioning information they expect to obtain a better control with bus operators in relation with e.g. reliability
- Since the TRAPRIO system creates a smoother driving they expect a limited decrease in the wear and tear on infrastructure and a reduction in the emissions
- They expect that the TRAPRIO system together with real-time bus information via media, at stops and onboard buses can further improve the effects of the TRAPRIO system.

Fleet Operators:

- The fleet operators expect that the TRAPRIO system can generate a less stressful and better comfort for their drivers
- The pre-emption gives the possibility for a better utilisation of vehicles.
- It is expected that 4-9% reduction of the costs is achievable caused mainly by a possibility to reduce the size of the fleet since the transport times have been shortened.
- The smoother driving is expected to give a lower fuel consumption and less wear and tear on the vehicles
- The TRAPRIO system combined with passenger information systems is expected to give a increase in the number of passengers
- They expect a greatly improved fleet management and operation efficiency caused by the continuous real-time monitoring of vehicle condition
- The improved fleet management and operation efficiency is expected to create a competitive advantage when negotiating with local authorities concerning new routes etc.
- In general they expect lower operation cost and higher revenue.

Application Possibilities

Passenger Information

A key factor influencing passenger satisfaction is accurate real-time information about arrival and departure times – onboard buses, at bus stops and via other media like the internet, pagers and mobile phones. Improving passenger satisfaction is key to attracting more passengers, decreasing private commuting, easing traffic congestion, improving the environment and creating higher revenue to the operators and/or keeping prices down.

For Passenger Information systems PositionTag locations are established before and after bus stops and other locations relevant to the specific passenger information system. When a bus passes a tag location, the Traffic Light Priority & Information (TIP) System calculates expected time of arrival and decides what passenger information to display where. Together with odometer readings and speed calculations this is used to calculate the expected time of arrival at each bus stop. Constantly monitoring the buses' position and speed makes it possible to dynamically changing the displayed arrival time, as the buses' approach changes due to the traffic situation.

Bus Terminal Management

As with passenger information, effective and informative bus terminals raise passenger satisfaction and the attractiveness of public transport.

With PositionTag locations in and around a bus terminal it is possible to collect information about arriving, departing and in-terminal bus traffic. This information can be used for passenger information, guiding passengers to the correct departure bays and displaying arrival, departure and connecting bus information.

The information can also be used for dynamic management of the terminals. Buses arriving to the terminal can be directed to arrival bays according to available space. In between arrival and departure buses can be directed to a waiting area away from the general terminal traffic. Buses departing can be directed from the waiting area to the departure bays according to available space and departure information including departure bay number can be displayed to waiting passengers.

Such a system will allow more traffic to be handled at smaller bus terminals, with a significant increased service to the public.

Fleet Management

The AVL system not only provides benefits to the public and authorities. Fleet operators can also utilise the system and benefit from the information and control opportunities that the system provides.

With PositionTag locations throughout the infrastructure and position equipment installed onboard a fleet of buses or other vehicles, it is possible to develop a fleet management system utilising the position and other data provided by the Traffic Information and Priority System. This gives the fleet operator an opportunity to monitor and control the exact whereabouts and condition of drivers and all vehicles in the fleet.

A fleet management system would require that the fleet operator have a main station or other computer system that can operate as main station. This can either function on data received directly from the vehicles or on processed data from the Traffic Information & Priority System.

Sensors can be used to monitor the condition of the vehicles, while interfacing to onboard equipment would allow the operator to remotely control these and communicate with the driver and passengers.

Any fleet operator, including utility and freight companies can use PositionTag locations already installed for traffic light priority and passenger information. As such the benefits of a TRAPRIO system could be expanded to cover many different public as well as private users, effectively extending the value of the system.

Operator Monitoring

Monitoring the performance of operators is especially important in areas where bus and emergency operations are privatised. Information like arrival/departure time, loading/unloading time and other information collected by the AVL system for passenger information, fleet management etc. can be used by local authorities to insure that agreed service levels are met.

Public transport planers to plan future routes, necessary capacity and schedules can further use the information.

Hospital Warning

Warning hospitals of approaching ambulances give doctors and other hospital personnel a chance to be ready when the ambulance arrive – saving valuable time. A warning system can be established by installing PositionTags at locations on all roads leading in to the hospital. When the ambulance pass such dedicated PositionTag location, the Traffic Control Centre sends a warning message directly to the hospital.

If the system onboard the ambulances interface to medical equipment, it is further possible to transmit medical data to the hospital in advance of arrival – giving doctors a chance to prepare arrival and treatment.

Access Control

With PositionTag locations at the entrants to limited access areas, such as bus-only roads, terminal and depot gates, etc. it is possible to operate an automatic access control system. When a vehicle mounted with an ActiveAntenna passes the PositionTag location at the entrants to a limited access area, the Traffic Control Centre sends a request for entry. Entry can be controlled by barriers or other means of enforcement.

Other Application Possibilities

With a computer in place in a vehicle it is possible to expand any application. In buses the computer can interface to ticket machines with automatic zone shifting, sensors for passenger counting, video surveillance, etc. The opportunities are practically limitless.