SPRUCING Up Your Bus Priority

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INTRODUCTION

Those who regularly attend the JCT Symposium, will probably remember the presentations by Mervyn Hallworth, from Leeds City Council, demonstrating the potential of a new software called SPRUCE (STM), that was being developed to provide flexible ways of achieving a high degree of selected vehicle priority within a coordinated fixed time UTC network. This paper provides an overview of how SPRUCE (STM) has been applied to provide central traffic light priority in Sheffield for buses operating the Yorkshire wide YourNextBus system.

BACKGROUND SPRUCE PROJECT

(Please note: If you are familiar with this project you may wish to skip to the next section. This section is a lightly abridged version of Mervyn Hallworth's JCT paper from 2006.)

SPRUCE provides a powerful and versatile means of making a Fixed Time UTC system respond in bespoke ways to specified conditions. Originally it was developed to give bus priority in a more intelligent way, but it is apparent that the applications are much broader, encompassing a range of intelligent plan selection not all related to priority.

'SPRUCE' (now standing for Selective PRogramming in a UtmC Environment) started as the software-based Priority Tool originally developed by Leeds City Council under the DfT sponsored UTMC01 project. After successful trialling a prototype version of the software in both Sheffield and Leeds, Leeds City Council funded a software development contract with TSEU (now Telent) to develop SPRUCE into a more robust software product, with increased functionality.

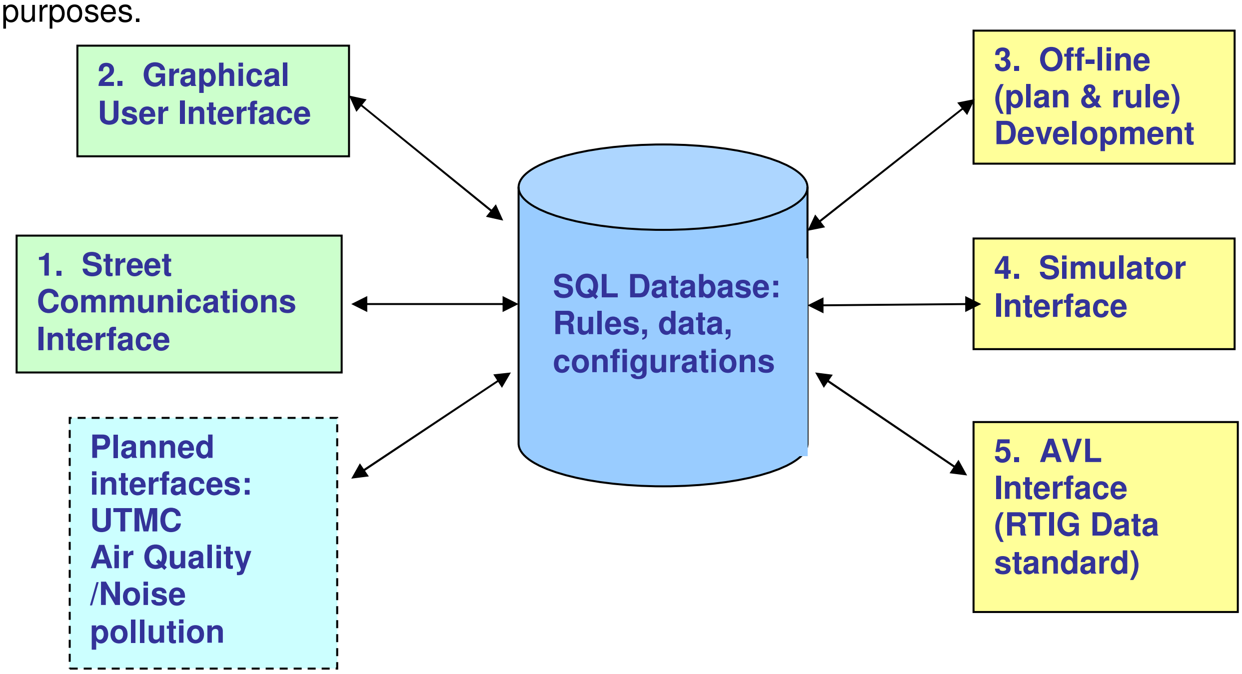
SPRUCE in its new incarnation can provide access not only to 'priority' facilities, but will apply to UTC plans the sort of user-programmable logic hitherto restricted to local traffic signal controllers.

The initial SPRUCE project was directed at the provision of flexible ways of achieving a high degree of selected vehicle priority within a coordinated fixed time UTC network. This led directly to the development of a prototype priority tool. The aim was to provide priority at groups of linked signals with interventions and reversions that maintained the smooth progress of general traffic through the network, while providing priority to a selectively detected vehicle. A choice of strategy options was to be possible depending on a combination of circumstances. These aims were achieved by combining the strategic control capability available via a centralised UTC system, with a logic capability superior to that found in either local signal controllers or existing fixed time UTC software.

On-street implementation of the prototype SPRUCE system was successfully carried out during field trials on the Sheffield tram scheme (see UTMC website: utmc.org.uk). This yielded over 70% reduction in delay through two junctions, and has been in operation for most of the period since August 2000. Similarly encouraging results were obtained from street trials on guided-buses in Leeds, and in a desktop study on trams in Croydon.

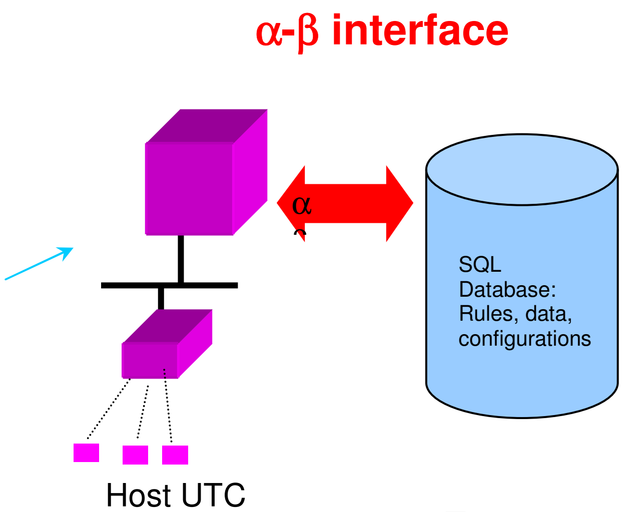
STM ARCHITECTURE

At the heart of STM is an SQL database. This stores all 'detector' and 'reply' data recovered from the street, timing plans for the junctions under control, the logical rules that determine which plans are to be applied and the set up information for the user interfaces. This allows the entire database to be copied off line for security, archive and simulation purposes.

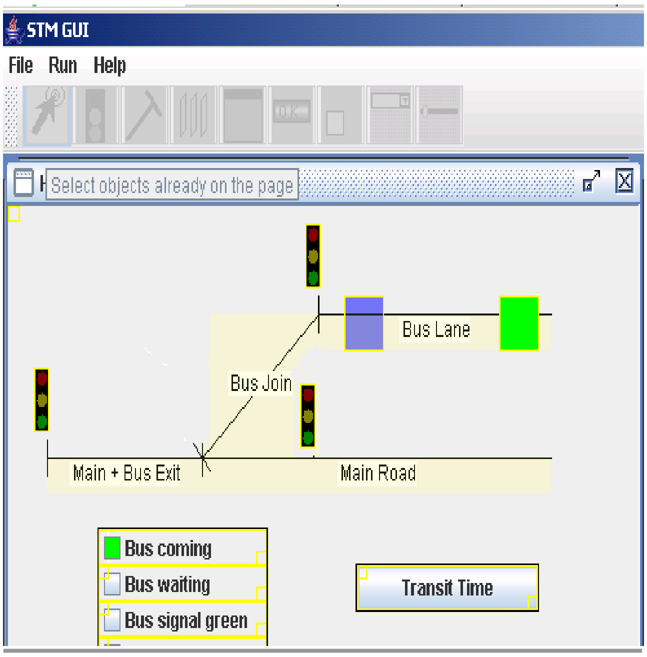


When connected to street, the system processes detector inputs, interprets logic, selects plans, and outputs stage forces - each second in synchronism with the host UTC system. In offline simulation mode, this process is speeded up. The various components making up the system are discussed in more detail below:

1. Street Communications Interface



The database interfaces to the street communications via existing UTC infrastructure.
It achieves this via an α-β (UTMCO1) interface, which enables STM to take control of a traffic signal network via a host UTC system.
In one direction STM receives vehicle detector data and G bit information, and in the other direction it sends back control messages.



2. Graphical User Interface (GUI)

A GUI is provided to enable the user to both monitor and influence STM run-time operation.

Diagrams representing individual or groups of signals can be generated, and these can include active symbols to monitor configurable inputs (e.g. a detected bus or the status of some logic element).

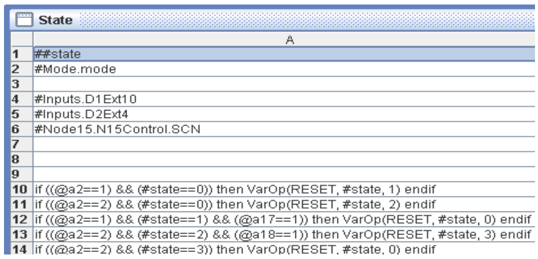
Users can also directly influence the STM logic relating to the selection of plans for a group of signals, by the use of on-screen buttons and slider bars.

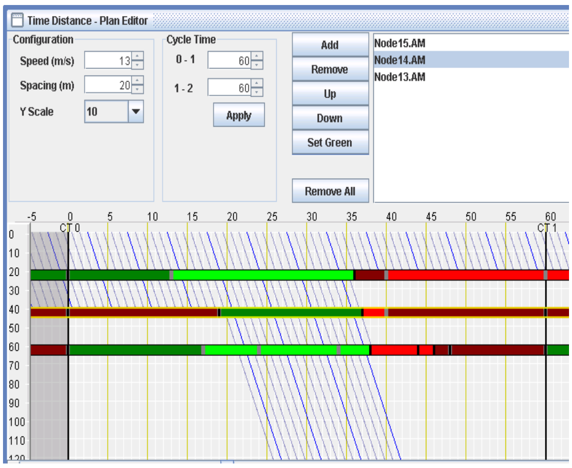
3. Off line (plan & rule) Development Tool (ODT)

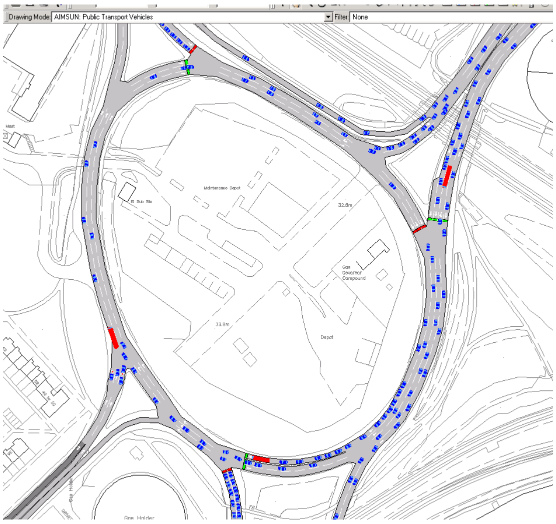
The ODT is used entirely off-line, principally to configure plans and related logic sheets. Users are provided with a 'cell based' language with which to configure plan selection logic – this include pre-defined *maths*, *Boolean*, *time-related* and *plan-related* functions. Users can also define their own functions where repetitive logic elements are required.

Theoretically presented with a 'blank sheet' for each logic configuration, in practise users will often re-use elements of previously generated code, and will be actively encouraged to adopt standardised logic and structures by the STM User Group.

The ODT also supports a Time-Distance diagram facility, to assist users in the design of priority interventions through groups of signals, and other applications involving signal coordination.



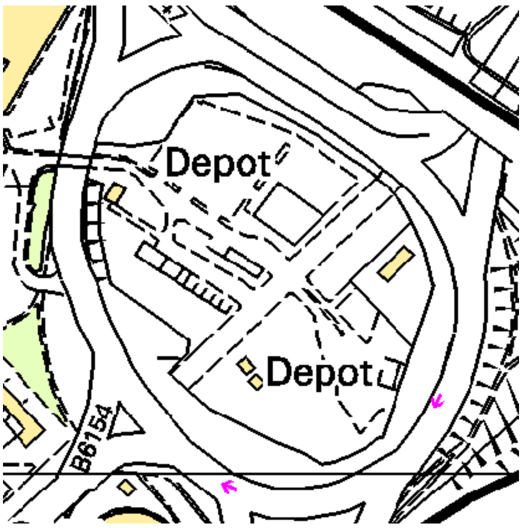




4. Simulation interface

An interface to micro-simulation models will allow new plans and control logic to be designed and tested using traffic simulations, before these are transferred to the online database for deployment on-street. It is advisable to test all strategies in this way, to ensure that logic and timings function as expected.

The interface (initially for AIMSUN, then Paramics & Vissim) passes detector inputs from the simulation to STM, and passes control signals in the opposite direction. Control signals are converted as required to the form required by the particular model simulation type.



5. Automatic Vehicle Location (AVL) Interface

An interface to an AVL system is provided based on the RTIG data standard. This allows buses to communicate their position at ‘virtual detector’ points to STM, via a centralised AVL system.

Centralised virtual detection opens up the whole of a UTC network to priority techniques - without the need to install local priority units or to carry out controller reconfigurations.

Virtual detectors can be committed to the system using a map-based viewer as shown (the AVL system in use in Leeds and Sheffield is supplied by ACIS).

STM functionality

STM is a control system which can be programmed, using logic functionality which should be well understood by designers of traffic signal controllers, so as to achieve techniques appropriate to the particular linked network of traffic signals. Strictly not a ‘strategy’ in itself, more a ‘strategy implementer’, STM is designed to provide a solution to most control situations – ultimately limited more by the imagination of the user than by software. The aim is:- If you can define your strategy in *long-hand*, you should be able to implement it in *logic*!

STM, by virtue of its powerful user programmable logic and its ability to allow programmed plan changes, can effectively provide a comprehensive ‘toolbox’ of strategies. A library of strategies based on the cumulative experience gained in such locations as Leeds and Sheffield will be developed over time and shared amongst users. In contrast to SCOOT, which is a broad brush strategy designed to optimise a globally calculated statistic, STM is a precision tool to handle specific situations in defined ways. With Fixed Time plans as a base (arguably the ultimate user-defined strategy) designers should be able to derive their own particular mix of ‘flexibility’ and ‘rigidity’. To help achieve this, two types of ‘plans’ will be available:

Fixed Time Micro plans: these are plans with fixed action times which can operate for *short but precise* periods - often for less than one signal cycle - and which can be called in or out of operation as required by suitable logic. In addition to allowing on-street timing changes to be related to ‘time-of-day’, Micro plans allow changes to be related to ‘time in cycle’.
Rule-based Micro plans: these plans can also be called in or out of operation at precise times in cycle, but need not necessarily contain ‘fixed’ timing values - they can contain variable values - depending on particular ‘rules’. At one extreme, a rule-based plan may have *none* of its timing values fixed and may be extremely flexible as a consequence. At the other extreme - with *all* its timing values fixed - it will revert to being a rigid fixed time Micro plan.

Strategies so far considered are mainly ‘priority’ based, but they are starting to include ‘non priority’ applications, consistent with the fact that STM will provide a more general programmable control tool. In considering the list of strategies below, it should be noted that in general the lower the frequency of events which ‘trigger’ the strategies (e.g. bus, tram, pedestrians etc.) the greater the potential benefits. The current list includes:

Offset & reversion strategy - plan timings are offset as necessary to suit the arrival time of a bus/tram, and then reverted to normal values. Appropriate where junctions need to retain synchronism with the wider UTC region. Strategy used in Sheffield Field Trials, Manor Top (from 2000) – average tram delay was reduced from 36 secs to 10 secs, through 2 junctions.

Cumulative offset strategy - plan timings are similarly offset to suit the bus/tram arrival time, but here offsets are cumulated instead of being reverted to normal values. Appropriate where junctions do not need to retain synchronism with the wider UTC region. Strategy can support a higher tram frequency than the above strategy – since time is not needed for the reversion process. Strategy used in Croydon Desktop study (2003) – average general traffic delay was reduced by over 40%, coupled with a reduction in tram delay.

Split change & reversion strategy - splits at one or more junctions are altered so as to change the coordination between junctions in favour of the bus/tram, and then reverted to the normal values. Appropriate where the bus/tram is not normally on the main coordinated route. Strategy used in Leeds, Halton Dial (from 2002) – average bus delay was reduced from 32 secs to 8 secs, through 2 junctions.

Queue management strategy - splits and cycle time are changed in advance of bus/tram arrival in order to reduce queues, which are then reverted to normal. Appropriate where there is sufficient time between bus/tram events to complete the necessary queue modulation. Strategy planned for junctions in Leeds.

Queue relocation strategy – splits changed on a cycle by cycle basis to relocate a particular queue. Appropriate for making environmental improvements or reducing bus/tram delay on a congested link. Strategy planned for Headingley in Leeds.

Intelligent demand-dependent strategy – cycle time and splits are abruptly changed in response to a demand for a particular stage, in order to maintain capacity. Appropriate where a critical junction in a UTC region is not demanded every cycle (e.g. pedestrian stage at a multi-stage junction). Strategy planned for junctions in Leeds and Sheffield.

Rule-linked strategy – offsets and splits are related to cycle time by a set of ‘rules’. Appropriate for groups of closely spaced nodes with specific coordination and queue constraints (e.g. signalised roundabouts). Strategy planned for a roundabout in Leeds.

The above list is not definitive, new or variant strategies will emerge once STM becomes widely used.

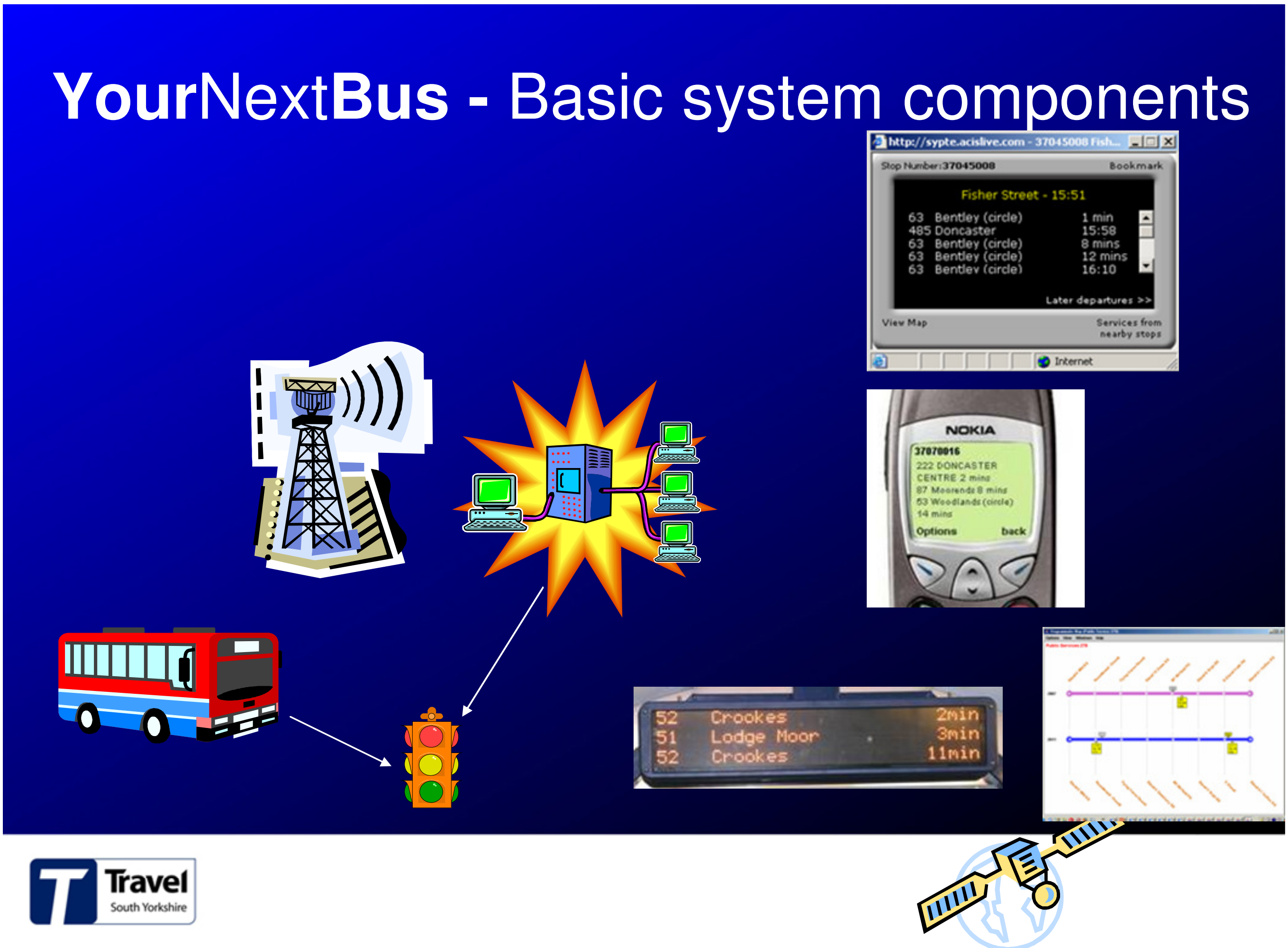
BACKGROUND YourNextBus PROJECT

In 2002 South and West Yorkshire Passenger Transport Executives (PTE's) formed a Strategic Alliance to procure a region wide Automatic Vehicle Location, Bus Priority and Real-Time Passenger Information System. The project was originally given the snappy title West & South Yorkshire Real Time Strategic Alliance (WSYRTSA), proof that if the scheme is good enough you don't have to have a smart acronym to get funding. Fortunately (WSYRTSA) was later rebranded as YourNextBus. The contract was awarded to ACIS later in 2002.

YourNextBus now includes North Yorkshire, Hull, East Ridings and York covering 2,200 services, 2600 equipped buses (836 in South Yorkshire), 34,000 bus stops and 42,000 journeys per day.

The key elements of the system are;

- Provision of real time information to the public via WEB/WAP, SMS / text message, bus station displays, interactive digital TV and on street displays.
- Fleet Mangement via Bus Net Live.
- Traffic light priority (TLP).
- Private Mobile Radio (PMR) network to communicate both voice and data, including GPS information, between the buses and the central systems.



Implementation of Bus Priority in Sheffield

Choices

The Traffic Light Priority (TLP) phase of the YourNextBus project was programmed to be in the second phase of the contract, this phase didn't start until 2006. However early on in the project a decision was made as to which approach Sheffield would take to implementing bus priority across the city once the ACIS system was finally in operation.

The TLP in the ACIS system, procured for YourNextBus, included two options for transmitting the TLP request from the bus;

> Option 1: Local priority messages sent over a lower powered unlicensed radio channel to a local TLP unit in an adjacent traffic signal controller.
> Option 2: Central priority messages, sent over a high power licensed PMR channel, transmitted via a gateway back to Urban Traffic Control (UTC).

Based on these two options, the choices for Sheffield of how to implement TLP were as follows;

1. Install local TLP units in every traffic signal controller and reconfigure the traffic signal controller to provide local bus priority. In the majority of cases this would have required an upgrade or full replacement of the traffic signal controller.
2. Install local TLP units in every traffic signal controller and relay the priority request back to UTC via the existing UTC communications link and input the request back into Bus SCOOT or similar adaptive system.
3. Central priority messages to UTC, input directly into STM which would then modify the normal UTC control plans to new plans to provide bus priority on street.

At the time of the initiation of the YourNextBus project Sheffield had already worked as a partner in the UTMC01 SPRUCE project, led by Leeds City Council. The potential of the STM software, then being developed by TSEU for Leeds, was obvious. This made the decision easy, central priority for all junctions with the exception of a few bus pre-signals and junctions where bus stops are too close to a junction where any communications lag would significantly affect priority.

Triggers

The ACIS TLP system developed for YourNextBus was specified to comply with the then emerging UK Real Time Information Group (RTIG) standard. The RTIG specification for TLP allows for 3 types of messages to be triggered and transmitted as the bus travels through the junction.

1. 'Registration' at some distance indicates that a vehicle is approaching;
2. 'Request' request immediate priority;
3. 'Clear' indicates that the vehicle has cleared the junction;

Messages type 1 and 3 are optional, so for a simple implementation only the 'Request' is used. This would be the case for Bus SCOOT, or for example with a junction configured for local priority using Siemen's bus priority facilities.

The South Yorkshire Supertram system uses a similar 4 trigger priority approach system, although the tramway uses transponder loops set into the tram track, rather than virtual triggers activated by the GPS on the bus. As a result there is a lot of experience in Sheffield of the benefits of multiple priority triggers. Therefore the 3 trigger virtual loop arrangement has been fully adopted for bus priority.

The ACIS trigger positioning tool allows relatively easy configuring via map based software. Each of the three types of triggers are mapped on to the system at each controlled junction, including pedestrian facilities, for every bus movement. Against every trigger a directional mask is added, to ensure the trigger is unidirectional, and bus services are allocated to each trigger selected from a drop down list of available services in that area. A limit of 299 triggers per route is set, limited by the processing times of the onboard bus equipment. This isn't usually a problem, but can be on some cross city routes. These triggers are then broadcast out across the PMR network to the on vehicle units. Currently we have 2500 triggers configured in Sheffield covering 389 junctions.

On Vehicle Unit
The system employs an on-bus Deltatrack unit, which at 30 second intervals updates the GPS position of the bus to the Central System across the PMR network,. This data is used to update the fleet management software and provide the real time passenger information. The Deltatrack unit is also constantly monitoring the GPS position and checking this against the stored table of TLP triggers for the service that the bus is running. If the bus is passing through a virtual trigger, the schedule and timetable information is referenced and calculations are performed to determine whether the bus is on, ahead or behind schedule and is subsequently allocated a schedule deviation code.

The RTIG specification defines the schedule deviation codes;

	Schedule Deviation in minutes	
Value	**From**	**To**
0	Schedule deviation not supplied	
1	>=1	<2
2	>=2	<3
3	>=3	<5
4	>=5	<7
5	>=7	<10
6	>=10	<15
7	>=15	
8	>-1	<1
9	<=-1	>-2
10	<=-2	>-3
11	<=-3	>-5
12	<=-5	>-7
13	<=-7	>-10
14	<=-10	>-15
15	<=-15	

Currently in the YourNextBus system the schedule deviation (SD) values 2 - 7 are defined as behind schedule and any bus with a SD value in this ranged will make TLP requests when it passes over the virtual trigger. The SD codes for late buses are further classified with priority codes;

SD codes 2 and 3 (>=2 to <5 minutes behind schedule) are classed as priority 1
SD codes 4 and 5 (>=5 to <10 minutes behind schedule) are classed as priority 2
SD codes 6 and 7 (>=10 behind schedule) are classed as priority 3

These priority levels can be use either locally or centrally to provide differing levels of signal priority.

The ACIS system also allows junction and vehicle specific overrides of SD. This can be done by specifying a trigger as a permanent trigger, so that the trigger would always send a TLP message regardless of schedule deviation for any route allocated to that trigger. For example this is used for all triggers at bus pre-signals in Sheffield. A similar option is also available to individual vehicles so that they always send TLP messages when ever they pass through a virtual trigger. Two examples of this type are the FTR bus in Leeds or Sheffield's Urban Traffic Control van, which is used for testing the setup and performance of TLP.

Once the on vehicle unit has processed that it should send a priority message, there is one last decision, central or local priority. This is defined in the configuration of the trigger. For Sheffield this is nearly always central, currently we only 4 local priority units installed at junctions.

The RTIG specification defines the TLP message;

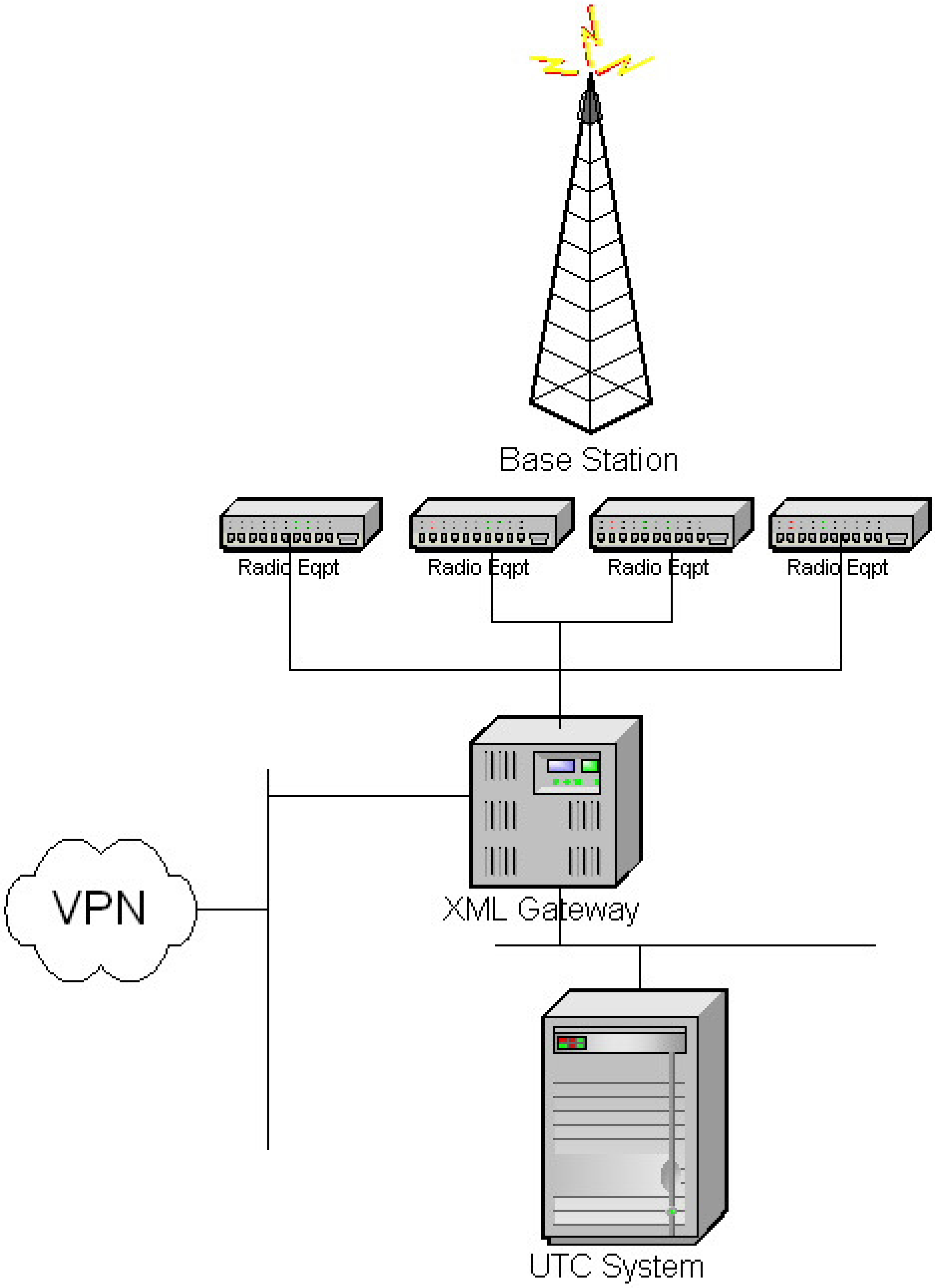
Field Name	**Contents**	**FieldRef**	**Length (in bits)**	**Optional**
Traffic Signal Number	0 to 16383	TSN	14	No
Movement Number	0 to 31	MN	5	No
Trigger Point	0 to 2	TP	2	No
Priority	0 to 3	P	2	No
Schedule Deviation	Coded deviation	SD	4	Yes
Local VCC	0 to 15	LVCC	4	Yes
Vehicle Number	0 to 8191	VN	13	Yes
Total			**44**	

If the trigger is configured for local priority, the TLP message is sent via the low powered radio transmitter on the bus to a radio receiver located in a signal head at the junction. A signal priority unit in the signal controller accepts the serial RS485 data from the local receiver, converts this into parallel data which is used to drive a bank of relays connected directly to the signal control equipment. The output from this can either be to initiate a local hurry call or bus priority if configured, or to relay the priority request back to UTC and initiate priority via SCOOT.
Each TLP message is sent 3 times, at random intervals, to ensure it is received by the signal controller.

Central triggers send the TLP message via the high powered licensed PMR channel, dedicated for central TLP messages, to the PMR base station. The message is sent twice at random intervals to minimise radio losses. It had been calculated that up to 8000 messages (4000 unique messages) can be transmitted per hour across a single dedicated PMR channel before data integrity would be affected.

XML Gateway

Central TLP messages sent to the base station are then passed to the XML Gateway which converts the serial message into XML format, time stamps the message and then forwards the message to the correct UTC system, for that traffic signal number, via an IP communications channel.



SPRUCE / STM The Conclusion

As described above, in Sheffield we currently have 2500 virtual TLP triggers configured covering 389 junctions, but only 4 of these junctions have local priority units.

We could install local TLP units at all these junctions and configure the junctions with local priority. However this would require new or upgraded traffic signal controllers for nearly every junction and for many of our controlled pedestrian facilities. Why not relay the messages back to UTC and into Bus SCOOT, but Sheffield is a mostly fixed time UTC based city. Our solution has to been to take advantage of the exciting new STM software developed for Leeds City Council by Telent.

STM on it's own is not a "shrink wrapped" solution. Plug it in and instant bus priority across the city would be a very nice idea. Once you plug STM in you do get an immediate database store for the thousands of XML priority requests that we do receive every day from the 2500 TLP triggers, which does provide a rich base of before priority timing data.

Newly installed STM is a blank canvas when it comes to providing traffic control, but fortunately for Sheffield, Mervyn & Ben Hallworth at Leeds City Council have already set up the base framework of "special conditioning" code from which we can start to build selective priority interventions in STM.

The interventions we have started with don't initially do anything clever or radical . They are simple priority extensions or recalls, with compensation built in to recover the junction, but they are capable of making full use of the registration, request and clear TLP triggers that ACIS provide. The timers and control plans set up in STM's Offline Development Tool (ODT) are tailored for each individual junction.

To date we have 28 junctions running selective bus priority using the ACIS system. 4 of these are operating with local units, as mentioned before, but the remainder are driven by STM via our Peek TMS UTC system. STM just takes control for the priority intervention and then hands back control to TMS.

The implementation of STM has started slowly, mostly due to conflicts of resources over the last couple of years during the syITS project, of which the purchase of STM was one part. However the pace of implementation is now quickening, we are committed to implementing bus priority at nearly another 100 junctions, using STM, before the end of this financial year. In addition we have plans for more complex interventions using STM, and not just for bus priority.

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Author Reg Hill, Cardiff County Council