SCOOT – THE FUTURE

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INTRODUCTION

The SCOOT Urban Traffic Control system is now operating in over 200 cities and towns worldwide. Since the first system was installed there has been a continuous program of research and development to provide new facilities to meet the requirements of the traffic manager. This paper describes the work which is currently being undertaken which will effect how SCOOT operates in four key areas: communications, congestion control, bus priority and puffin pedestrian facilities.

COMMUNICATIONS

All control systems rely on timely accurate data from their sensors to provide good responsive control. This requirement is equally true of a policeman on point duty responding to the vehicles that he can see as to a sophisticated UTC system such as SCOOT. Communication systems are continually developing and analogue dedicated lines are likely to become increasingly expensive and possibly not supported at all. Newer data communications systems are packet based. Guaranteed second-by-second data delivery by packet switched means is expensive and ways of removing SCOOT's reliance on it have been sought.

To this end, SCOOT is currently being modified to use time-stamped data. The objective of the changes is to maintain the excellent level of traffic control that SCOOT provides, but allow for small time delays in communications between the UTC software and Outstation Transmission Units (OTU).

To maintain efficient traffic control and management, SCOOT needs to continue to receive and transmit timely data. Therefore, the aim of time stamping the data is to accommodate short delays in data transmission whilst maintaining current data in SCOOT. The objective is not to allow for frequent long delays in data transmission that would result in poor traffic control.

Using packet switched data transmission introduces uncertainty into the data transmission process, which must be allowed for. Data may be:

- Delayed
- Out of order
- Repeated
- Missed

However, if a complete message is received (e.g. the four bits of detector occupancy in a second), then that data will be correct.

Data are transmitted to and from OTUs for 3 purposes:

1. Detector data from OTU to SCOOT, currently 4 bits per second per detector
2. Control data from SCOOT to OTU, currently n bits per second per node indicating changes of stage, e.g.
   F1 (force stage 1)
3. Green reply bits from OTU to SCOOT, currently m bits per second per node indicating current green being shown to street, e.g.
   G1 (UTC stage 1 green)

For detector data coming from the OTU, the aim is to maintain the delivery of second-by-second data for good traffic control. The modifications allow SCOOT to operate successfully with communications that do not guarantee the time or order of data delivery, but normally deliver the data with only very short delays (i.e. up to 4 seconds), if any.

For control data sent from SCOOT to the OTU, the time stamping is used to ensure that commands are applied in the correct order. Using time stamping, however, allows the control method between the UTC software and the OTU to be changed to reduce the data flow by sending messages of the form,

"Change to stage 2 at 11:39:05"

rather than sending control bits each second.

To accompany this development the resolution at which SCOOT stores some of the flow data has been reduced from 4 seconds to 1 second. The effect of this change is to counter the possible reduction in timeliness that the loss of second-by-second communication will introduce. It is predicted that as long as the delays are of the order of a only a few seconds the move away from guaranteed second- by-second communication will be negligible.

CONGESTION SUPERVISOR

From the outset the optimisers in SCOOT have acted in a way so as to help to control congestion. SCOOT links are assigned a congestion importance factor when the system is set up. This allows SCOOT to operate basic queue management as it will act to minimise queues on links with a higher congestion importance. Over the years a number of additional facilities have been provided. These include 'local' facilities such as the ability to specify fixed offsets for congested conditions; SCOOT will automatically move the offset to these congestion offsets as congestion increases.

They also include features to carry out more sophisticated queue management such as the gating facility. Gating is used to limit the flow of traffic into a particularly sensitive area by restraining traffic on user specified roads. It can act at a distance so that queues can be relocated to areas where they are less of a problem.

Whilst the facilities provided are of proven value, there can be a problem in knowing where and how best to deploy them. This is aggravated by a scarcity of resources within local authorities. It is important therefore, that the limited resources are used efficiently and directed at dealing with the problems that will achieve the greatest benefit.

To assist in this a congestion supervisor is being developed based on the information available in SCOOT. The aim of the supervisor will be to continuously monitor congestion throughout the SCOOT controlled network, to identify links causing serious problems and to diagnose the probable reason for congestion emanating from those links.

The congestion problem and the recommended action to take will then be reported to the users.

Examples of functions that the supervisor will perform or the information which the supervisor will provide are:

- Identify nodes that are the cause of the congestion problem
- Calculate congestion offsets on "short" links
- Identify possible changes to congestion importance factor
- Diagnose problems when there are faulty links
- Report/diagnose problems where the degree of saturation is low
- Diagnose and report where junction overloaded

The aim of the supervisor will be to target regularly recurring congestion rather than congestion caused through incidents.

STAGE SKIPPING FOR BUS PRIORITY

Priority facilities for individual buses (or other high priority vehicles) were first introduced in SCOOT Version 3.1 (Bowen and Bretherton (1)) which was released in 1996. The current version of SCOOT Version 4.5 described by Bretherton (2), includes differential priority which allows the traffic engineer, in co-operation with the bus operator, to target priority to buses that are most in need of it. The most likely beneficiaries are buses that are running late against the timetable, or on services that run to a headway rather than schedule, those that have a particularly large headway to the previous bus.

The new development, which has arisen from a project UG298 jointly funded by the Department for Transport (DfT) and Transport for London (TfL) has taken bus priority to the next stage. All the previous work was constrained by the normal stage order, but UG298 has looked at the effects of using stage skipping within SCOOT to give extra priority to buses in addition to that already provided. With the existing bus priority logic if a bus is detected on red then it receives priority using a recall. The recall logic shortens the current stage and all stages between the current one and the bus priority stage. However all stages have to run for at least a minimum green before the priority stage may start. With stage skipping it is possible to skip intermediate stages to give an earlier green to a bus. In addition the logic has been enhanced to allow 'stage truncation' which may be applicable at junctions with demand dependent stages. The 'truncation' logic comes in to play when there is no demand for the demand dependent stage

The project started with a review of existing experience of stage skipping, with a particular interest in any knowledge of safety issues. The SCOOT kernel software was then developed so as to enable stage skipping and truncation to be implemented.. A simulation study tested the new software and looked at the potential benefits of stage skipping in a wide range of situations. In parallel the new SCOOT kernel was installed in the London UTC system and TfL developed the UTC software to enable stage skipping to be implemented on street. Extensive on-street trials of stage skipping have been carried out at five sites in London which has allowed guidelines for its use to be developed.

Stage skipping definition

- SCOOT will normally run the normal SCOOT stage sequence without skipping stages.

- SCOOT may skip stages only as permitted by UTC in the list of stages passed from UTC to SCOOT each second.

- SCOOT may skip stages only in order to benefit a bus. This means that, following the detection of a bus, SCOOT may skip stages to allow the bus to receive green earlier than otherwise. SCOOT may not skip stages once the bus is modelled as having departed, except to benefit a different bus.

Stage truncation definition

- Consider a junction with a demand-dependent stage. Without loss of generality, assume a three-stage junction with the obvious stage numbering.

SCOOT stage	UTC stage	Description
1	F1	'main road'
2	F2	demand-dependent stage. If F2 is not demanded on street, F1 continues to run
3	F3	'side road'

- Consider that a bus on the side road requiring SCOOT stage 3 is detected during SCOOT stage 1 and that UTC stage F2 is not demanded on street. Under the existing SCOOT logic, SCOOT stage 2 will run for its minimum length before allowing SCOOT stage 3 to run to give priority to the bus.

- The 'truncation' logic now allows that when UTC stage F2 does not run on street and a bus is detected requiring SCOOT stage 3 that SCOOT, as soon as it knows that F2 is not demanded on-street, is able to stop SCOOT stage 2 immediately, rather than needing to allow SCOOT stage 2 to run for its minimum length, to give priority to the bus. Truncation is subject to the usual recall constraints such as target saturation.

Stage skipping control and constraints

To provide some control over the traffic conditions when stage skipping is allowed or how frequently stages can be skipped a number of user determined parameters can be set. The most important of these are:

- *Bus mode* (node based) - SCOOT may not skip stages unless the node's bus mode permits stage skipping.

- For stage skipping to operate it is necessary for recalls to be allowed at a node.

- *Skipping inhibit period* – The length of time (in seconds) which must elapse between one skip and the next (the minimum allowed is one second)

- *Skipping inhibit cycles* – The number of cycles which must elapse between one skip and the next (i.e. setting a value of 1, will allow a skip every other cycle (this is the minimum allowed))

- *Bus link skipping saturation* – If the degree of saturation on any link whose green is to be skipped is greater than the *Bus link skipping saturation* then the stage skipping will not take place

- *Node skipping priority level* - SCOOT may not skip stages at node N to benefit a bus of priority level P unless $0 < PN \leqslant P$, where PN is N's *node skipping priority level*

- *Skipping priority level difference* – If there are two or more buses requiring priority at a node at the same time and they are green on different stages then the decision whether or not to skip a stage is dependent on the skipping priority level difference parameter. Where there is a bus of priority level p requiring priority at a node, SCOOT may not skip a stage giving green to that bus except in order to give priority to a bus of priority level P, where $P > p + n$ and n is the node's *skipping priority level difference*.

- *Bus skipping recovery* – After a stage has been skipped a period of recovery occurs to bring the timings back into line with the normal SCOOT optimisation. Any of the 4 recovery methods available for normal SCOOT bus priority can be selected.

On-street trials

There was a desire to trial stage skipping early in the project, particularly to start the safety studies. It was not possible, however, to use SCOOT to control stage skipping as the logic and software had to be developed as part of the project. Therefore the first trial of stage skipping took place at an isolated junction on the Bromley Road that is controlled by system-D Vehicle Actuation, VA. The next trial also did not use SCOOT, it was at a SCOOT controlled junction on the Camden Road, but stage skipping was implemented using the TfL System Activated Plan Selection (SAPS), technique. When the stage skipping logic in SCOOT had been developed and tested, it was trialled at the same junction on Camden Road and at the next junction towards central London. The final two trials using SCOOT were at Seven Sisters Road and Tottenham High Road.

The trials at each site had two components, a video survey and a journey time survey. The video recordings were made of pedestrian and vehicle movements and analysed to look for any effect of stage skipping on the behaviour of users and the safety of the operation of the junction. The journey time survey measured the time that buses and other vehicles took to traverse the junction on each approach. The surveys were designed to evaluate the additional effects of stage skipping on top of the benefit that normal bus priority achieves.

As previously mentioned the SCOOT stage skipping logic includes several parameters to control when a stage could be skipped depending on traffic conditions and the previous actions of stage skipping. The main parameter used to prevent skipping occurring too often under SCOOT control was the *skipping inhibit period* parameter that sets a limit on the minimum time between stage skips. In addition, at all sites, a stage could not be skipped in two successive cycles. The *Bus link skipping saturation* parameter limits the action of stage skipping when junctions are very busy. In most cases this was set to 150%, a high value that meant that stage skipping was unlikely to be inhibited by the degree of saturation at the junction.

On-street trial results

Safety: Videos were taken of all movements at four junctions and analysed to look for any adverse safety implications of stage skipping as enacted, that is with skipping of pedestrian stage strictly forbidden. There were no indications from those studies of pedestrian safety being adversely affected by stage skipping. There was considerable evidence of pedestrians crossing roads when they saw an opportunity rather than waiting for a green signal, but there was no evidence of enhanced risk due to stage skipping.

The videos were also analysed for evidence of red-running. Drivers did not appear to be confused by the change in stage order resulting in them running red lights. At the junction of Camden Road and Brecknock Road, a considerable number of drivers turned right against a red light. This behaviour was not, however, associated with stage skipping, but due to responding to the wrong traffic signal.

Delays to buses: Buses enjoyed lower delays when stage skipping was operating. Typically, at a junction where the skipped roads were not too busy (e.g. the junction is less than 80% saturated or the skipped roads require no more than their minimum green), a bus would be delayed by about 4 seconds less between the bus beacon and the stopline when stage skipping was operating than when it was not. This benefit is in addition to the benefit from the existing bus priority logic in SCOOT. A higher benefit was measured at the junction operating under isolated control, but that result may not be typical as the VA detectors were not working at that junction. The interaction between stage skipping and co-ordination of the traffic signals is not clear. At some junctions more benefit was measured in one direction than the other, but the overall conclusion is that stage skipping can offer benefits to buses in a co-ordinated system. The results from the final trial site provide a note of caution.

At that junction the side roads, where green can be skipped, are busier than at the other trial sites. To avoid excessive disruption of the junction, it is necessary to utilise the *Bus link skipping saturation* parameter that prevents stage skipping when the junction is very busy. However, as a result of stage skipping being inhibited at some times, the benefits to buses are considerably reduced, to 1 second per bus at the trial junction. Uninhibited stage skipping resulted in a benefit of 3½ seconds per bus, between the bus detector and the stopline. However, it also caused significantly more delay to non-bus traffic on the main road, as well as on the side road, and buses would have been delayed in these longer queues before reaching the bus beacons. The best estimate of the net benefit to buses is about 1 second per bus, the same as when stage skipping was inhibited when the junction was very busy. It is worth noting that if there had been bus lanes on the approaches to the junction so that buses could by-pass the queues and the extra delay to non-bus traffic could be accepted, then uninhibited stage skipping would be expected to give a benefit of 3½ seconds per bus at this junction.

Delays to other vehicles: Stage skipping increased the overall delay to non-bus traffic. At Seven Sister Road, there was a clear picture of appreciable extra delay on the side road, 14 seconds per vehicle, and a small decrease on the main road causing an overall increase of over 1 second per vehicle. The increase in side road delays was expected. Although the recovery logic can compensate the side road by giving it extra green after a skip this will not fully make up for the serious disruption caused by having to wait an extra cycle for a green. Similarly a small reduction on the main road is possible because of the possibility of extra green time. This result was typical of junctions where the road being skipped is not too busy.

The final trial demonstrated the possibility of extra delay on the main road as well as the side road. Because of the high demand on the side road, a large queue could build up on it after it was skipped and SCOOT would then respond to that queue in subsequent cycles. The detrimental effect to the main road of responding to the problems on the side road outweighed the benefit of the extra green when stage skipping was freely allowed. With uninhibited stage skipping delays on the main road increased by about 2 seconds per vehicle and more on the side road. There was a very clear overall disbenefit under this strategy. Unfortunately during the survey days when the *Bus link skipping saturation* parameter was used to restrict stage skipping to less saturated cycles the flow on one side road dropped considerably preventing robust conclusions on the effect of controlled stage skipping at a busy junction.

Accident study

In addition to the study using video data, the safety effects have also been investigated using personal injury accident data. For the two junctions where stage skipping has been operating for over 1 year this has been analysed for the periods before and after the installation of the stage skipping facilities. The results of the study supported the findings of the on-street trials. There was no evidence of any increase in accident risk.

Guidelines and Recommendations

Based on the experience of the on street trials and simulation testing, guidelines and recommendations for implementing stage skipping in conjunction with SCOOT bus priority have been produced:

Benefit to buses: When restrictions are at their minimum level, stage skipping gives good benefits to buses in the range 2.5 to 6 seconds per bus per junction, depending on the junction and flow conditions. Typically, at junctions where the skipped roads are not too busy, the saving in delay averages about 4 seconds per bus. This benefit is in addition to the benefit from the existing bus priority logic in SCOOT. The highest benefits are achieved at junctions where the benefits of normal bus priority are low (i.e. where there are few extensions due to bus detection close to the junction and where the side road stage is on or close to a minimum).

Effect on general traffic: On average there is a small increase of about 1 second per vehicle in the delay to general traffic when stages are skipped. The main traffic that is disbenefitted is the traffic on the side road being skipped. In some cases of low side road flow, there is an overall benefit to general traffic, since extra green is given to the busier main road.

At junctions where the links whose green is skipped are busy the increase in delay to general traffic can be large if the stage skipping is uninhibited. To avoid excessive disruption of the junction, it is necessary to utilise the stage skipping saturation parameter to prevent stage skipping when the junction is very busy. However, imposing restrictions as to when stage skipping can occur will reduce the benefit to buses.

Effect on safety: At the sites in London where stage skipping has been introduced, there is no indication that the accident risk has increased. It should be stressed; however that great care has been taken when stage skipping has been implemented in London. Users of each trial junction were warned of the change in control by the installation of standard warning signs on the approaches. In addition, the following principles were adhered to:

- Main road stages should not be skipped
- Pedestrian phases should not be skipped – a possible exception is where the pedestrian phase being skipped occurs more than once per cycle.

It is recommended that the above principles are followed at all installations and that the accident statistics at junctions where stage skipping has been introduced are carefully monitored. The impact of stage skipping on accident rate and in particular on the severity of accidents should be assessed.

Other recommendations:

- When stage skipping is to be introduced at a junction the stage order should be reviewed as it may be desirable to re-order the normal stage sequence. This is especially likely at junctions where it is not permitted to skip a particular stage.

- Truncation is applicable at some junctions with demand dependent stages. It can provide good benefits to buses with very little disbenefit in terms of its effects on general traffic or safety. It is therefore recommended that it is implemented at all sites where it is appropriate.

PUFFIN PEDESTRIAN CROSSINGS

Puffin (Pedestrian User Friendly Intelligent) Crossings are relatively new and are intended to become the UK standard for signal controlled pedestrian facilities at stand-alone crossings and junctions.

Puffin Crossings have near-side pedestrian signal heads. Kerbside detectors are used to cancel pedestrian demands that are no longer required. There is no flashing amber period (as under Pelican control), instead on-crossing pedestrian detectors are used to extend a variable all-red period.

At present when SCOOT is controlling a Pelican crossing, the feedback logic in SCOOT assumes (correctly) that the pedestrian stage is a fixed length. With the introduction of the Puffin crossing as a replacement for Pelicans, the length of time that vehicles are stopped due to pedestrians is no longer fixed, because of the variable intergreen following the pedestrian stage. It is therefore possible to improve on the way that SCOOT currently models puffin pedestrian crossings and puffin pedestrian facilities at junctions. The SCOOT kernel software is now being modified to correctly model the variable intergreen period that follows the pedestrian stage rather than assuming it runs for a fixed length. SCOOT should then accurately model the on-street behaviour of Puffins and Puffin pedestrian facilities and thus provide improved control and reductions in delay to vehicles.

CONCLUSIONS

The modification to SCOOT to allow the use of time-stamped data, should maintain the excellent level of traffic control, but allow for small time delays in communications between the UTC software and Outstation Transmission Units (OTU). This should increase the range of communication options available and in particular allow the use of some of the newer data communications systems e.g. ADSL, GPRS, G3 etc which are packet based.

The other new facilities being developed should further increase SCOOT's ability to manage traffic effectively and in accordance with the objectives of the traffic manager. The congestion supervisor should afford the operator a better understanding of the congestion occurring in the network and should facilitate the use of the extensive congestion tools available in SCOOT.

The stage skipping logic will allow the operator to provide a higher level of priority to buses at junctions where it can be applied.

The correct modelling of the variable intergreen period should improve the control of puffin pedestrian crossings and junctions with puffin pedestrian facilites.

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