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# ARTERIAL ADAPTIVE TRAFFIC CONTROL

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An approach is proposed for real-time coordination of signal phase timings for a network. Currently, network coordination is done using off-line methods, which are based on average traffic volumes for various movements. On-line approaches adapt off-line methods by constantly inputting updated average volumes computed from detector data over the "last" decision horizon. Our method first identifies platoons and predicts their movement in the network (i.e., their arrival times at intersections, their sizes, and their speeds) by fusing and filtering the traffic data obtained, from various sources, in the last few minutes. The signals are set so that the predicted platoons are provided appropriate green times to optimise a given performance criterion. If two platoons demanding conflicting movements arrive at an intersection at the same time, then either one or the other will be given priority for green time, or one of them is split to maximize the given measure of performance. This study discusses how such conflicts are resolved and the corresponding algorithmic procedure.

***Keyword:*** *traffic light, controlled intersection, arterial movement, adaptive algorithm, traffic control, decision tree, prediction, platoon*

## 1. Introduction

Road traffic is an essential part of modern society and has put a high demand on road networks. Traffic network congestion causes delays that add substantial costs to society and businesses on a daily basis and also increase emissions and the risk of accidents. To alleviate congestion, public transport can be improved or the infrastructure can be expanded. In urban areas, the latter is often impossible due to residential areas adjacent to the existing roads. A more subtle way to improve the network performance is to make better use of the existing roads, which can be achieved in part by proper setting of traffic signal parameters.

## 2. Setting of Task

We will try to explain why real time technologies are receiving more and more popularity. We will show weak points of off-line methods.

Our task is to develop adaptive traffic control system for real-time traffic management which is able to coordinate signal controlled intersections to improve overall traffic system performance. This paper makes special emphasis on the decision tree algorithm used for traffic control on an arterial highway.

## 3. Off-Line Approaches

The basic ingredients of off-line approaches include a) a traffic flow model and b) an algorithm for optimising a specified performance criterion (this criterion could be a weighted sum of several performance indices). For example, in TRANSYT [1], vehicles are "loaded" onto the network at given origins and are propagated through the network in accordance with a traffic flow model. Traffic controls affect the movement of these vehicles, and numerical optimisation (gradient search) is performed to find controls that optimise the specified performance criterion. In MAXBAND [2] and PASSER II [3], vehicles are loaded on an arterial highway, and traffic signals on that arterial highway are coordinated to optimise a performance criterion, which often relates to the number of stops. Because these are off-line methods, assumptions on the traffic loads are based on historical average volumes, which are uniformly loaded onto the arterial highways. This results in an assumption of platoons of uniform size and identical speeds.

The time-distance diagram on a single arterial highway is shown on Figure 1. The goal of off-line arterial progression algorithms, such as MAXBAND and PASSER II, is to set the signal timings so that the number of vehicles that can traverse the arterial highway in either direction without stopping (other similar criteria may be incorporated) is maximized.

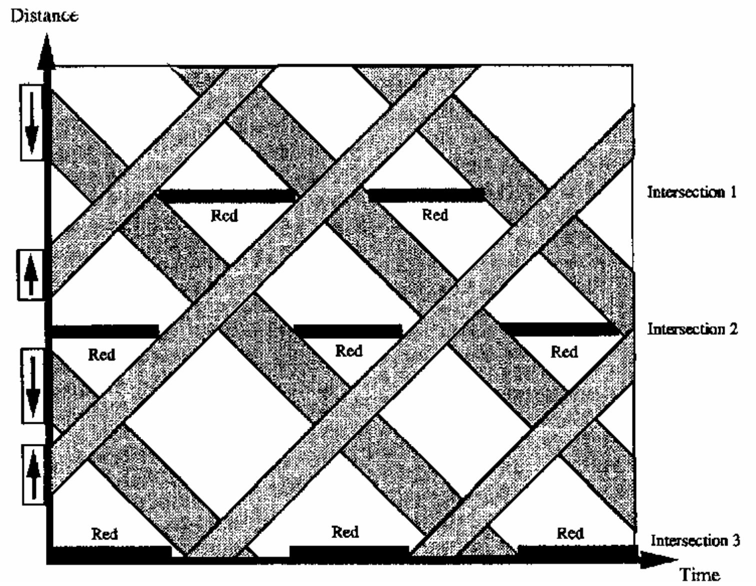


*Figure 1.* The MAXBAND concept

The figure shows these bands of green times. Note the following drawbacks: it is assumed that sets of platoons of equal size are distributed in a cyclic manner, and that platoons travel at the same constant speed.

The time-distance diagram on Figure 2 a) shows platoons of different sizes and different speeds. Because the green times required for these platoons are different from those required for the uniform case shown on Figure 1, the smooth anticipated progression is disrupted. By slightly adjusting the red times, it may be possible to reinstate the green bands for the given platoons with their own sizes and speeds (see Figure 2 b)).

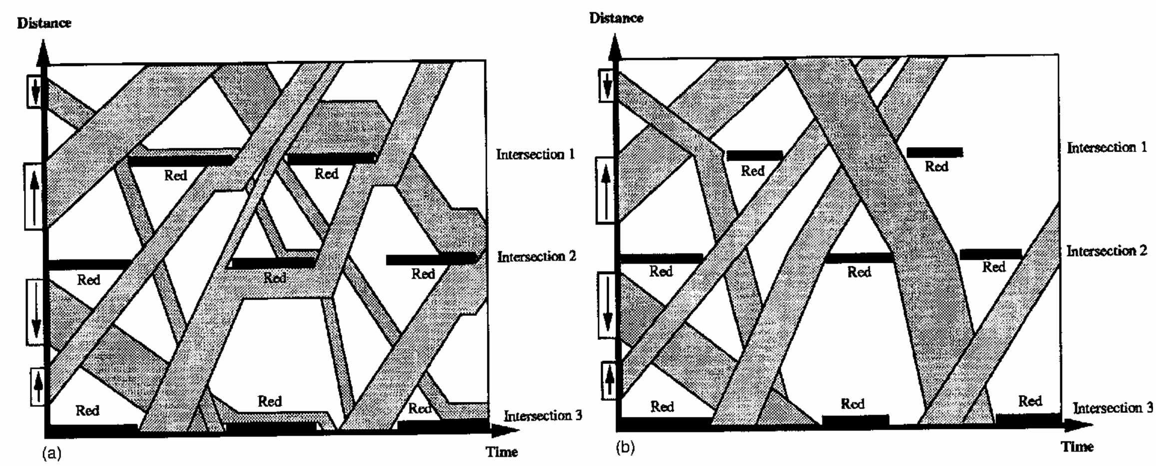


*Figure 2.* a) Actual MAXBAND performance; b) a new concept for single arteries

Thus off-line systems are not flexible enough and nowadays condition of urban streets requires more effective solutions. So the issue will cover a real-time algorithm of traffic control.

If two platoons demanding conflicting movements arrive at an intersection at the same time, then either one or the other will be given priority for green time, or one of them is split to maximize the given measure of performance. The main goal of the algorithm, that will be discussed, is optimal real-time solution of such conflicts.

## 4. Optimisation

The basic idea of the method can be understood by considering the following example. Figure 3 shows a small network with several platoons of vehicles travelling in different directions. Platoons are defined from observed detector data as a flow density above a pre-specified level for some length of time. Each platoon is characterized in terms of size (number of vehicles) and speed.

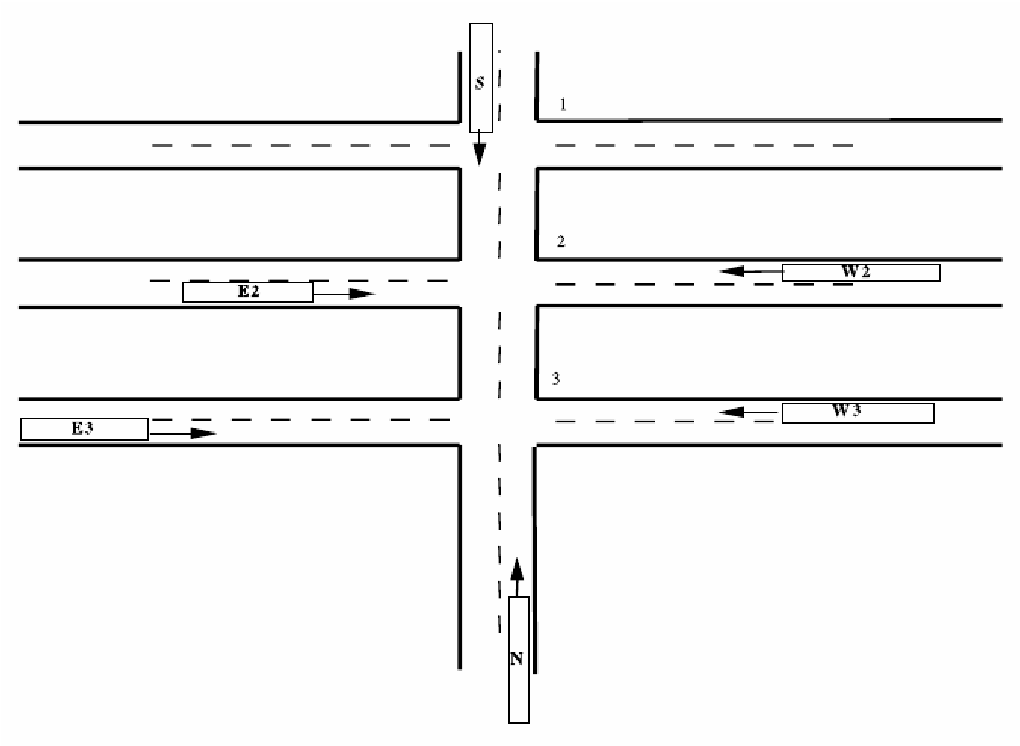


*Figure 3.* Example network

If the intersecting platoons fit exactly within the red times shown here, then it is not necessary to resolve green-time demand of conflicting movements. On the other hand, if flows at an intersection produced a concurrent green-time demand for conflicting movements, then the conflict must be resolved by determining to which movement the green time must be allocated. Figure 3 that shows platoons on two other perpendicular roads at Intersections 2 and 3 illustrates this scenario.

The algorithm makes a forward pass in time. When a conflict arises a decision node in a tree is formed; the types of decisions at this node include: a) give green time to Platoon A, b) give green time to platoon B, or c) split Platoon A (or Platoon B, because only one or the other platoon needs to be split). Each branch of the tree is propagated over time to keep track of the total performance up to the decision node plus the performance on the link associated with the potential decision.

Figure 4 gives the current prediction of the movement of the platoons shown on Figure 3. The first demand conflict arises between Platoons N and W3 at Intersection 3. To resolve the conflict, Platoon N (Figure 5 a)) is split or platoon W3 is stopped (Figure 5 b)). Considering the resulting predictions shown on Figure 5 a), the next conflict arises between Platoons S and E3. Here the decision is either to stop Platoon S (Figure 5 c)) or Stop E3 (Figure 5 d)). In this way, a decision tree is formed that keeps track of various candidate decisions as demand conflicts arise. For this illustration, the decision tree for the predictions that arise for various decisions is given on Figure 6.

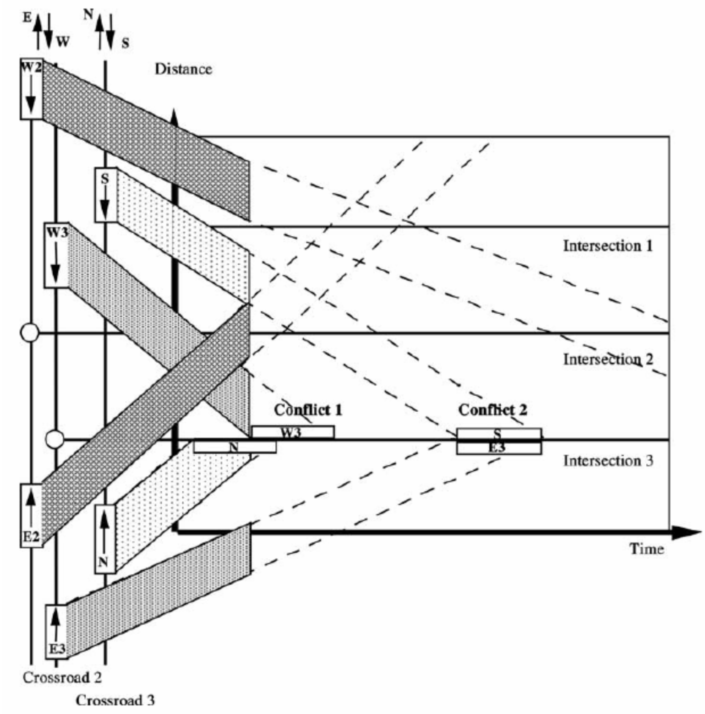


*Figure 4.* Time-space diagram for the example of Figure 3

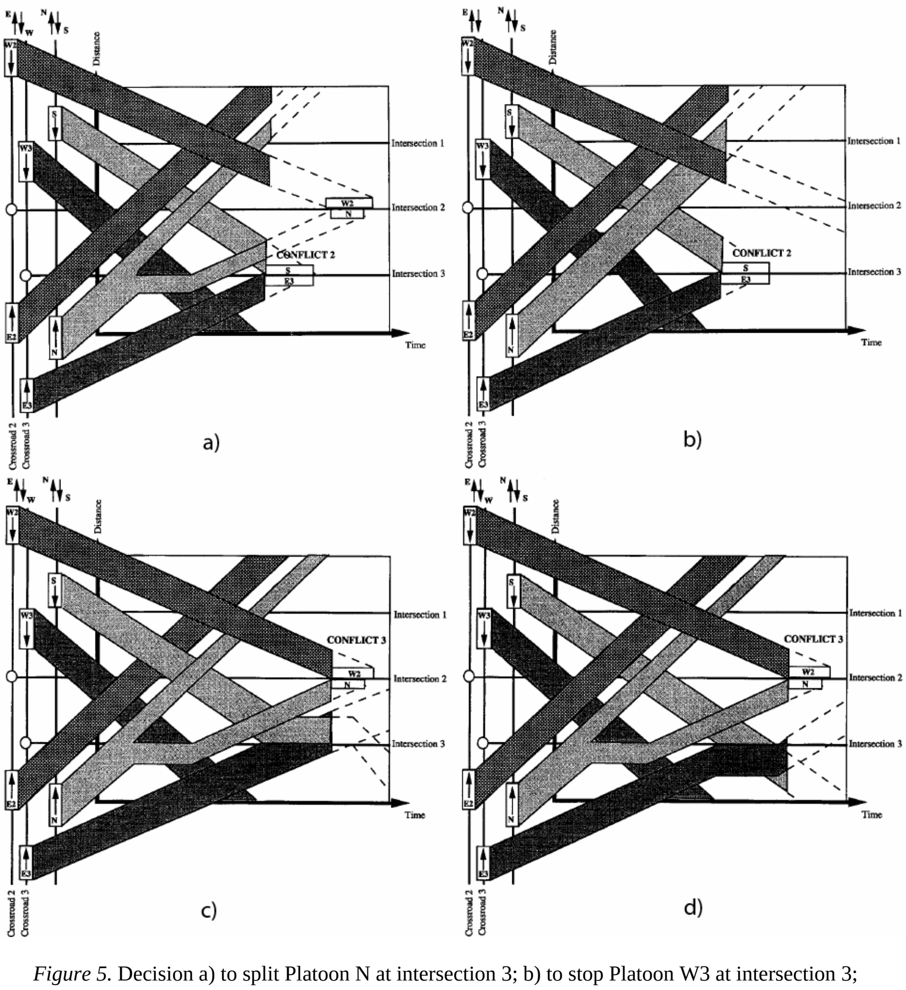


*Figure 5.* Decision a) to split Platoon N at intersection 3; b) to stop Platoon W3 at intersection 3;
c) to stop Platoon S at intersection; 3 d) to stop Platoon E3 at intersection

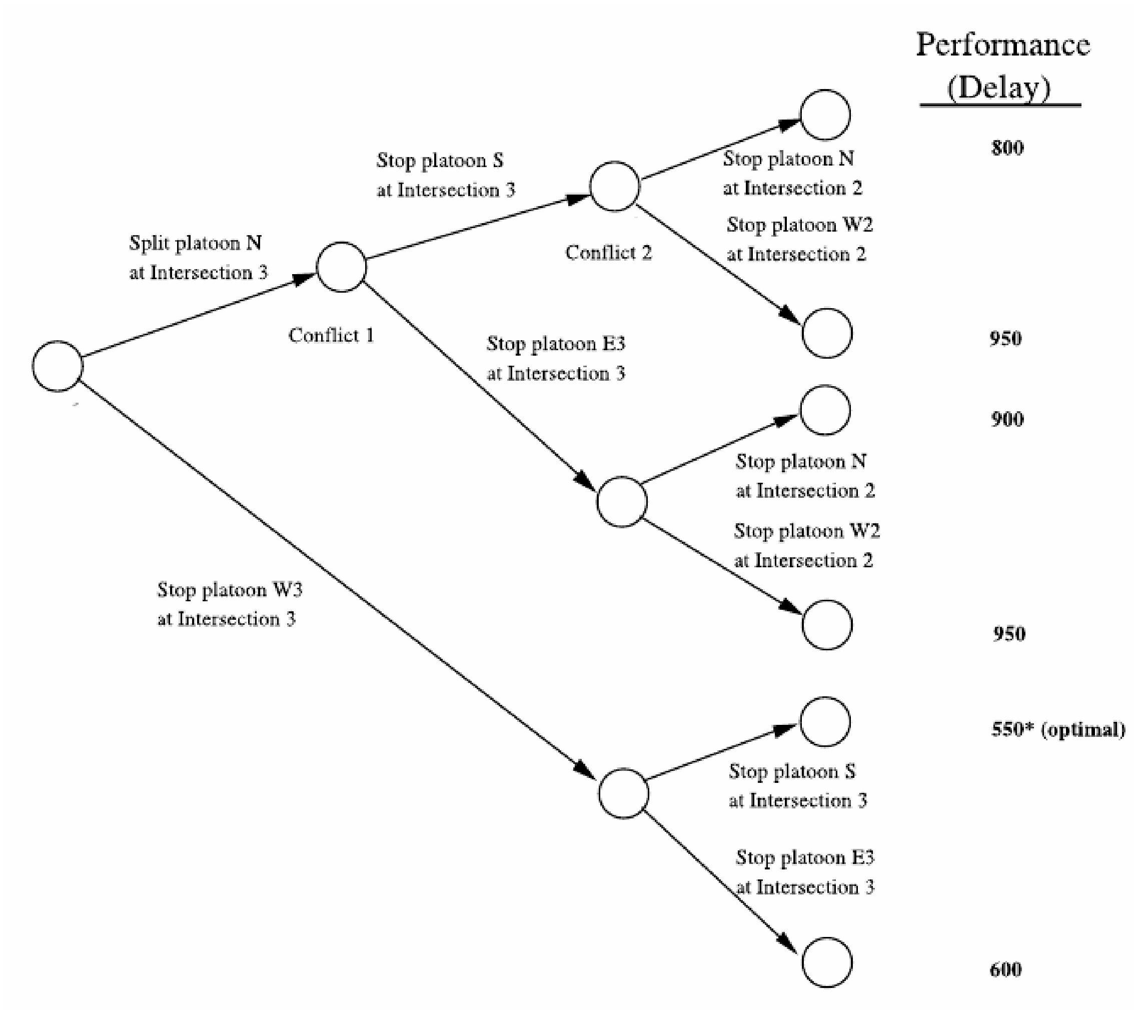


*Figure 6.* Decision tree for the example of Figure 3

When the time horizon is reached, associated with each end node will be the total cost of the all the decisions leading up to the node on the path from the root of the decision tree to the end node (leaf) of the decision tree. Selecting the one with minimum cost provides the least cost trajectory of conflict resolution decisions. A final backward pass provides a phase plan within the time horizon considered for the identified platoons. This is passed to the next level of the hierarchical traffic control system (intersection control logic) as constraints (and, hence, an initial cut at a sequence of phases) that specify the "winning phase" from the outcome of each conflict resolution on the optimal root-to-leaf path in the decision tree. Further optimisation is performed at the intersection level, at which more detailed data on individual vehicle movement are gathered. For the platoons shown on Figure 3, choosing the path with optimum performance (in this case minimum total delay), the resulting optimal decisions from the decision tree are shown on Figure 7 that includes the red and green times for the N-S arterial highway. It indicates that at Intersection 3 Platoon N should not be stopped but Platoon W3 should be stopped and, later. Platoon E3 should not be stopped but Platoon S should be stopped, when the corresponding demand conflicts arise.

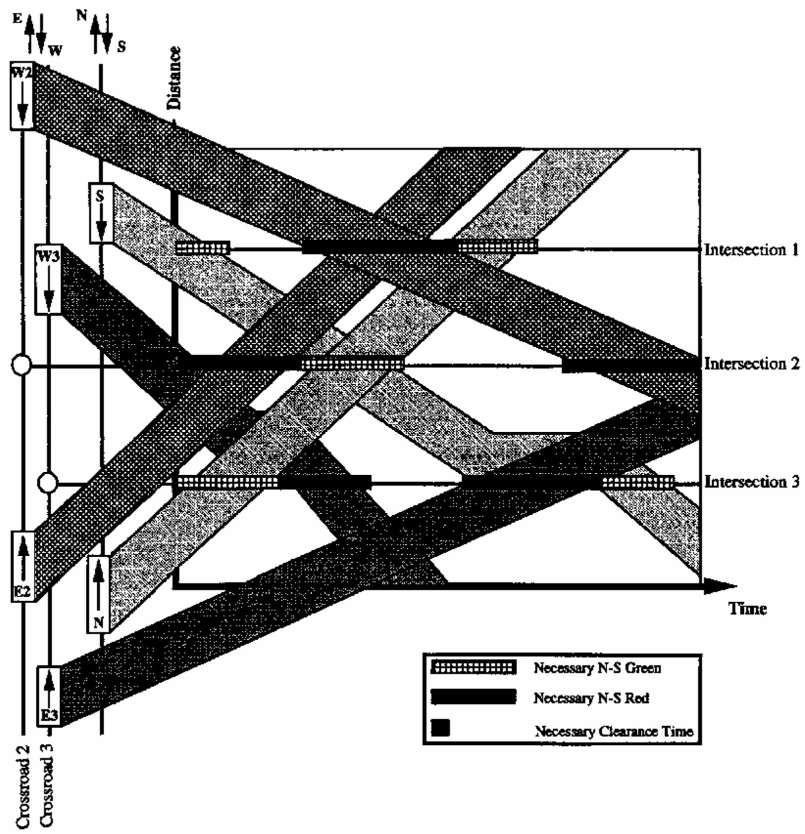


*Figure 7.* The north-south "red" and "green" phases for optimum decisions

The advantages of the algorithm approach include:

Using real-time data, the algorithm explicitly identifies the platoons and predicts their movement in the network; the method also sets traffic signals to respond to the identified platoons.

The algorithm does not necessarily require a predetermined sequence of phases. The output provides an initial cut at a sequence of phases for further optimisation at the lower intersection level.

A final issue that needs to be resolved in the method is the computation of performance measures, (e.g. the total number of stops, total delay, etc.). For real-time applications, these performance measures are needed quickly so that the performance criterion may be optimised in real time. A detailed simulation becomes computationally unwieldy when the simulation model is used as a function evaluator (i.e., for evaluating the performance function for each candidate signal setting) in an optimisation routine. To be in the proper range for the optimisations being performed at the intersection level, only approximate values for optimal signal timings are necessary at this level of hierarchy.

## 5. Implementation Issues

Detectors for platoon identification should be set at each arterial intersection and directly before intersections on crossroads.

The following issues must be considered for the code to be effective in providing good if not optimal solutions and efficient for real-time applications.

- Filtering detector data for identifying platoons,
- Initialisation of the algorithm, and
- Propagating the algorithm through time.

The definition of platoons for traffic coordination depends on the level of traffic in the network. In low congestion with vehicles travelling at high speeds, a platoon may be composed of as few as three cars having an average headway of 2 seconds. On a more heavily congested road, a platoon may consist of many more cars with an average headway of 1 sec. In any case, if a traffic engineer looks at vehicle detector data, that engineer can easily recognize platoons. Any platoon identification algorithm in which the goal of the algorithm is to filter out individual cars and identify platoons should be able to emulate the decisions of a traffic engineer. Several algorithms are being explored to identify platoons based on concepts of low-pass filters, threshold rules, etc. To develop the algorithm, a platoon identifier is used based on two user-specified threshold parameters: maximum headway between two vehicles in the same platoon and the minimum number of vehicles that constitute a platoon. Further research and evaluation is recommended for the development of an appropriate platoon identifier.

The algorithm starts with an initial solution of phase timings and associated measure of performance. The initial phase timings could have been developed off-line using a program such as TRANSYT, the initial phase timings could be given for the next few minutes. The initial phase timings define the first node on the decision tree. The measure of performance associated with the initial phasing becomes an upper bound (UB) on the performance

## 6. Conclusions

An approach is proposed for real-time coordination of signal phase timings for an arterial highway. Real-time traffic data are operated to optimise the measure of performance. It is envisioned that this procedure will be suitable for light-to-moderate traffic conditions, but not over-saturated conditions. The method should perform as well as or better than off-line methods such as PASSER II, MAXBAND, and TRANSYT. Farther research and testing are planned.

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