VS-PLUS

NEUTRAL, INDEPENDENT, THOUSANDS OPERATIONAL GLOBALLY

The VS-PLUS Control Ideas

Brief Description

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1 GENERAL OVERVIEW

Traffic-actuated, standardized and parameter-defined controller programs pursue two objectives: On the one hand the objective is to achieve optimum and transparent traffic control from a traffic engineering perspective. *Optimum* means low loss times to minimize delay for road users, thus simultaneously achieving a minimum of air pollution. *Transparent* means generating a phase sequence that is understandable to all road users. A road user should essentially be served within reasonable time and he should not need to wait unnecessarily and without any visible reason. On the other hand, the objective is to master the operation of a traffic signal with the least possible effort. The operator knows the process of a new installation or retiming thanks to a few parameter tables which are identical for all installations. Without any programming skills, modifications can be dealt with simply by changing parameters.

To ensure that the following description of traffic-actuated control is understandable, we need to define two basic VS-PLUS terms in addition to commonly used traffic engineering terminology

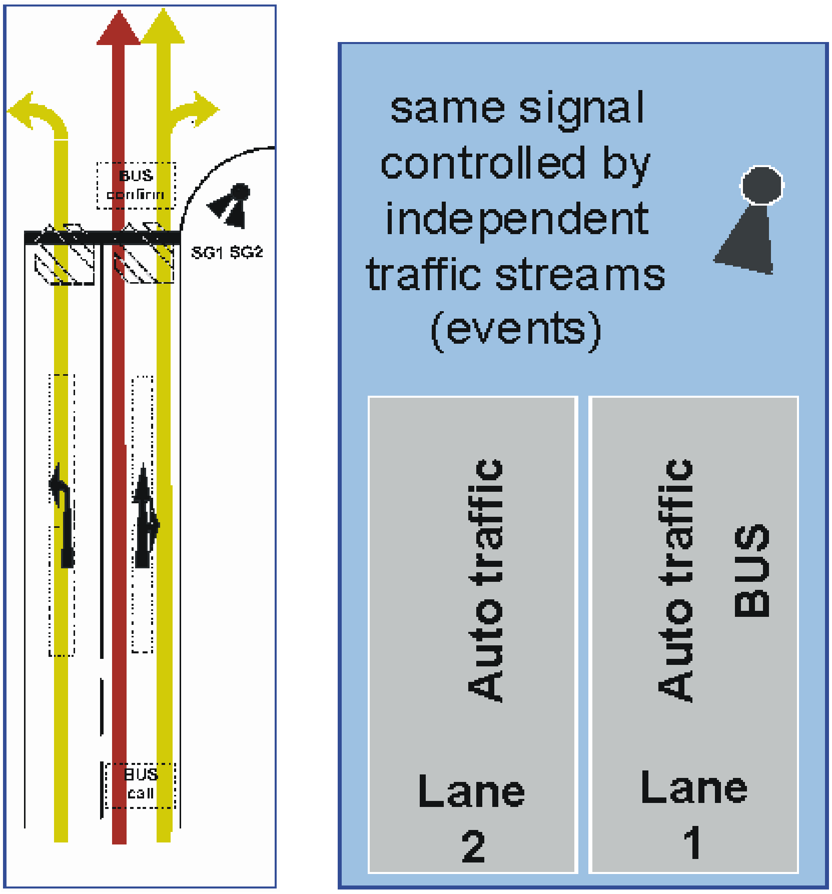

Figure 1: Definition of traffic stream

The first term is *traffic stream*. In contrast to conventional descriptions, a new, clear distinction is made between the traffic engineering term of traffic stream and the signal(s) assigned to it. All descriptions and definitions relevant to traffic engineering refer to the traffic stream as a unit. In control engineering terms, a traffic stream is a feedback loop with a measuring element (detector) and a control element (signal). At the same time, it is possible for two different traffic streams to be assigned to one and the same signal or, conversely, several signals may be assigned to one traffic stream. In the former case, this may be a bus traveling on the general purpose traffic lane. In the second case, it may be a general purpose traffic movement with two offset traffic signals as often used for turns onto divided highways.

The second term is the *frame signal plan* which is different from the well-known signal timing plan. A frame signal plan is no longer interpreted as a switching command as in the case of the traditional signal timing plan, but is used as a control signal for traffic-actuated control of a traffic stream. The frame signal plan is defined for each single traffic stream. Thus, each traffic engineering unit can be influenced directly or, respectively, controlled in terms of control engineering.

The control strategy is defined by developing the frame signal plan. It can range from consistent coordination within the conventional sense, coordination with passive and active green band extension, or fully traffic-actuated control.

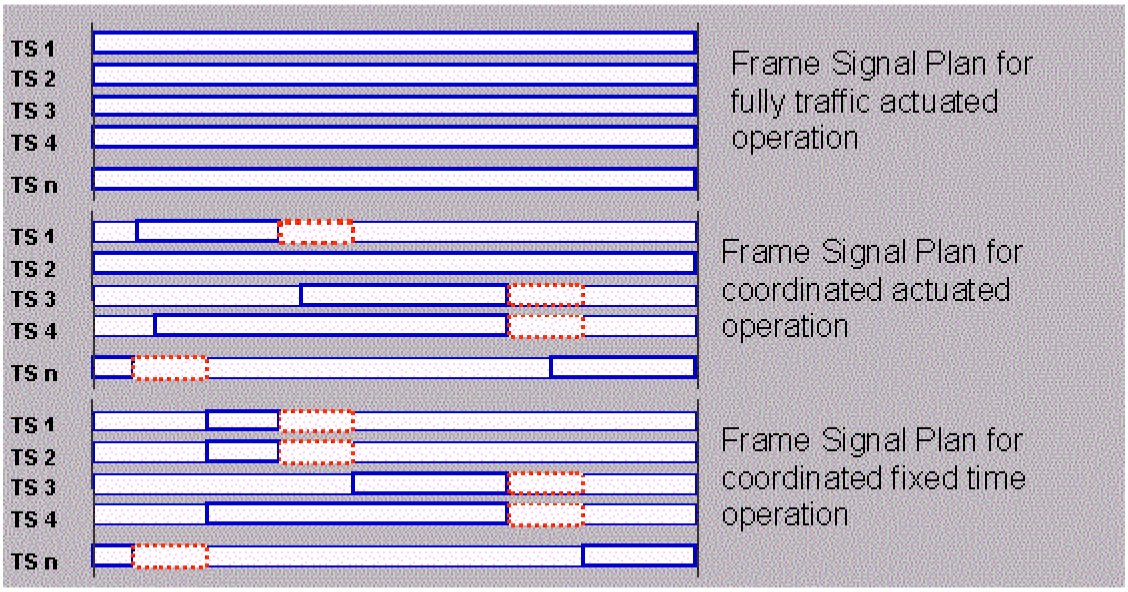

Figure 2: Frame signal plans

2 HOW DOES TRAFFIC-ACTUATED CONTROL WORK WITH VS-PLUS?

First of all, VS-PLUS processes all detector information. Then VS-PLUS checks for each traffic stream its demand, either as a call during red or as an extension during green. A detector signal does not result in a traffic stream demand until the particular traffic stream's permissive period as defined by the frame signal plan. Multiple parameters are available to balance the need for extending an active signal phase as a result of demand for its associated traffic streams and the demand of called conflict phase. The results this check are stored in state values for each traffic stream.

0 = Traffic stream inactive

1 = Traffic stream demand in intervention mode 1
2 = Traffic stream demand in intervention mode 2
3 = Traffic stream demand in intervention mode 3
4 = Traffic stream demand in intervention mode 4
5 = Traffic stream demand in intervention mode 5

8 = Green command
9 = Green command issued
10 = Green time G_{min1}
11 = Green time G_{min2}
12 = Green time G_{max1}
13 = Green time G_{max2}
14 = Green time G_{max2} with traffic
15 = Green without traffic

19 = Special red command
20 = Issue red command
21 = Red command issued

Figure 3: VS-PLUS state values

These form the information basis for the kernel of the control process, the **phase grouping**. For each demanding traffic stream, the phase grouping process computes a *priority value*. The result of this process is the new phase grouping to be implemented. All traffic streams that are to receive green next and are not in conflict with each other are listed in descending order of priority. The phase grouping is processed in the last step of the control process. In other words, the green and red commands for the associated signal phases are issued for each traffic stream. Since the phase grouping process only dealt with demanding traffic streams, non-demanding and non-conflicting traffic streams can now also be added.

The control logic is structured so that its decisions do not constantly contradict each other, thus generating an uncontrolled traffic process.

3 HOW DOES PHASE GROUPING WORK?

Now that traffic-actuated control has been summarized, the phase grouping process will be described in greater detail. As already mentioned, phase grouping is the central part of the control process. The other program parts either supply or execute tasks of phase grouping process.

First of all, all demanding traffic streams are evaluated. A classification of all demanding traffic streams into six priority elements according to the illustration below is the basis for this evaluation.

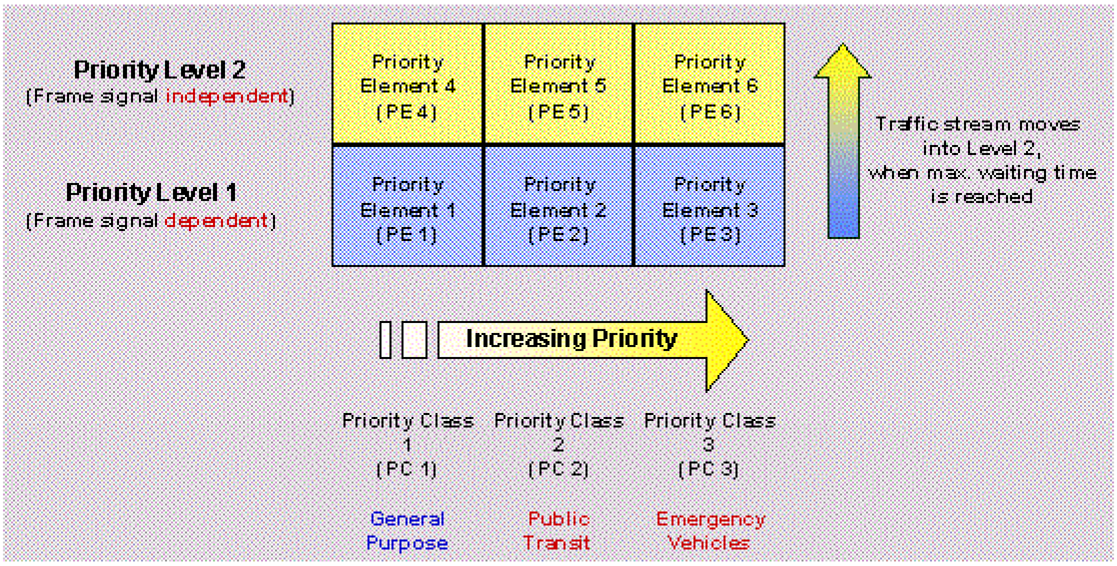

Figure 4: Priority elements

While priority element #6 has the highest priority, priority element #1 has the lowest priority. The assignment of traffic streams to the three **priority classes** (columns) is fixed. It is part of the base timing parameter set. General purpose traffic is generally in priority class #1 and public transit in priority class #2. Priority class #3 was conceived for special cases such as emergency vehicle and railroad preemption. Assignment to the two **priority levels** (rows) #1 and #2 is dynamic. Depending on the waiting time since the first call or detector actuation, the traffic stream switches from the low to the high priority level as soon as the **maximum waiting time** has elapsed. It is important to note though that calls in priority level #1 are governed by the frame signal plan, while calls in priority level #2 are frame signal plan independent.

Thus, different degrees of priority assignment can be realized dynamically, above all with public transit. In priority level #1 public transit must subordinate itself to coordination, while in priority level #2 it can be granted priority without consideration of coordination.

Once the traffic streams are assigned to the priority elements, the actual phase grouping process can begin. First of all, a **main stream** is defined for each priority element and is entered in the required grouping. Cyclic sequences correspond to the usual methods of control. Delay times can be minimized with such cyclic sequences, thus optimizing the performance of the traffic operation. Experience also shows that, in contrast to non-cyclic sequences, road users accept cyclic sequences better. These are the two reasons why the main streams are defined on the basis of a **main sequence**, which is polled cyclically and can be defined for each priority class. Once the main streams have been defined for each priority element, so-called secondary streams are now added in accordance with a **secondary sequence**. Each main stream has its own secondary sequence for demanding traffic streams. As a further option, the secondary streams can be defined for selected frame signal plans on the basis of the main sequence.

When using this option, all traffic streams that do not conflict with a main stream are considered as secondary streams. This method of control is appropriate for non-peak periods when repetitions (i.e., short cycles) and greater loss times as the result of additional clearance intervals are not critical.

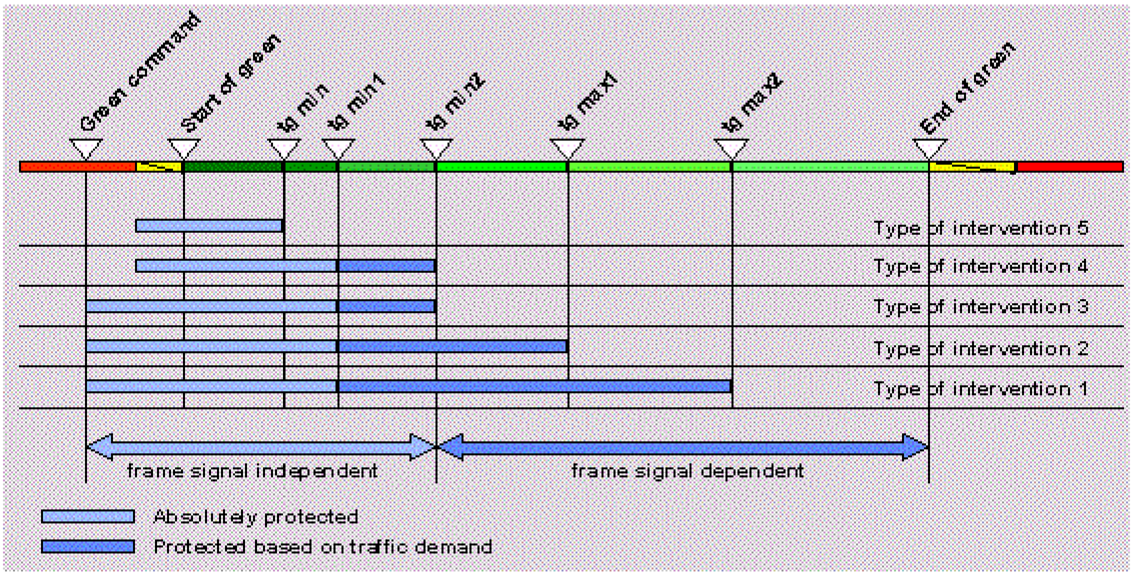

Figure 5: Types of interventions

The above description defines how the next phase grouping is developed from demanding traffic streams. It is understood that only traffic streams that are eligible for green are considered in this process. During every check, this signifies a check of those traffic streams that are currently green. Therefore, which criteria have to be fulfilled for a traffic stream to to be served and thus for conflicting traffic streams to be terminated? The answer to this question depends on the priority with which a traffic stream can intervene. Its priority which, on the one hand, is given by its priority element and, on the other hand, by its current waiting time, determines the **type of intervention** which refers to the conflicting traffic stream. It defines the green time after which a conflicting traffic stream may be terminated. The type of intervention itself increases dynamically with increasing waiting time starting with the registration of the first call of that traffic stream. There are five staggered types of intervention.

The weakest type of intervention (#1) takes into account the range between the green command and the start of green and the maximum possible extension of green. This type of intervention applies to the normal sequence without any higher priority interventions. The strongest and most extreme type of intervention (#5) merely respects the minimum green time safeguarded by the controller. Green commands are even withdrawn after having been issued. This type of intervention is used in exceptional cases only (i.e., emergency vehicles or railroad preemption). If a demanding traffic stream is permitted to terminate all conflicting traffic streams, while keeping to its type of intervention, it is entered into the phase grouping to be serviced next. Otherwise, the check is repeated during the next time step.

In this way, a new potential phase grouping is evaluated every second and is switched at the end of the time step. In doing so, non-conflicting traffic streams that have no demand can be added to supplement a new phase grouping.

Various parts of this description mention parameters for influencing the traffic control process. It is not possible to list all parameters here; however, an overview will provide hints as to the available possibilities. Besides the traffic engineering parameters, there are tabular definitions for influencing the process sequence and defining the particular field installation.

The first table contains **detector parameters**. It is used to define the call and extension response of the detectors. A plausible sequence can be guaranteed only with correct traffic detection. The goal is to minimize the waiting time for all road users and thus air pollution. Essentially, this means that unnecessary green time must be reassigned. That means that green should not be initiated without traffic demand and green should not be extended after traffic cleared the approach.

The second table contains **traffic stream parameters**. These are used to define the demand and extension response of the traffic stream. Traffic stream parameters include the above-mentioned control and maximum green times. They also contain parameters defining the response during red or green without traffic demand.

The third table contains **phase grouping parameters**. This table is the most important one. It defines the traffic control process. Setting up the main and secondary sequences requires a great deal of experience and presumes precise observation of local traffic operations.

In addition to these three essential parameter tables, there are tables for special problems such as transit priority, congestion, flow control monitoring etc. as well as parameters for defining controller settings.

4 WHAT ARE THE CONTROLLER REQUIREMENTS FOR VS-PLUS?

First of all, a controller must fulfill all technical requirements for autonomous operation. The necessary computing power and memory capacity for parameter tables must be guaranteed. Currently, these requirements are fulfilled by the TYPE 2070 Advanced Transportation Controller as specified by the California Department of Transportation (CALTRANS) which is available from multiple vendors.

The controller must also be capable of receiving frame signal plans or program selection commands from a control center. If the control center only sends program selection commands, the frame signal plans must be stored in the controller and must be capable of being synchronized with the control center. Secondly, parameters must be easily modifiable. Preferably, this is done with a portable personal computer.

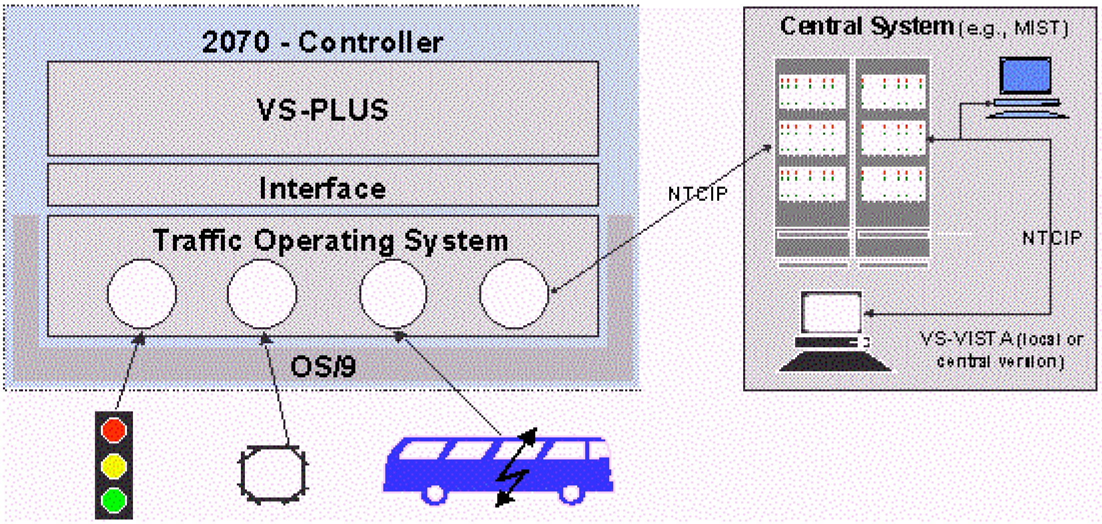

Figure 6: Software and hardware modules

5 DATA FILE

The standard VS-PLUS control is written in the programming language C.

Traffic control with VS-PLUS does not work with signal phases, only with traffic streams. Green and red commands are issued to the associated signal phases. An interface file (H-File) allows for standardized traffic engineering applications (i.e., timing plans) regardless of the controller platform.

The advantage of a high-level programming language such as C is that all parameters can be stored in tables and each parameter can be named.

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