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Introduction

SynchroGreen® is a real-time Adaptive Signal Control Technology (ASCT) solution from Trafficware. SynchroGreen collects traffic data at signalized intersections, analyzes the data for changing trends, and adjusts traffic signal timings in real time based on the current demand. SynchroGreen is a revolutionary software-based ASCT that can be implemented in many existing traffic controllers. This product uses standard (non-proprietary) vehicle detection technology and provides an intuitive interface and platform to implement ASCT. The purpose of this white paper is to familiarize prospective users with the capabilities of SynchroGreen by detailing the technical elements, system requirements, benefits, and applications of this ASCT.

Adaptive Signal Control Technology

Simply put, an ASCT adjusts signal timing plans in real time “based on the current traffic conditions, demand, and system capacity” (1). ASCT is an emerging technology quickly gaining momentum in the United States. While early ASCT systems date back to the 1970s and early 1980s, prior generations of ASCT have mainly been used for research purposes, and have not been designed or developed for large-scale deployment (1). In addition to improvements in ASCT algorithms and logic, the newest generation of ASCT benefits from modern traffic controller design, micro-processing, advancements in vehicle detection, and high-speed communications to provide more reliable adaptive operations for rapid large-scale deployment. The Federal Highway Administration (FHWA) states that ASCT is “proven and market ready” and furthermore recommends that agencies explore this technology to improve safety and reduce congestion (2).

Implementing ASCT maximizes the capacity of an existing traffic system.
Implementing ASCT maximizes the capacity of an existing traffic system. ASCT is most effectively applied where dynamic traffic patterns occur, and actuated-coordinated timing plans cannot reasonably accommodate fluctuating traffic conditions. Primary advantages of ASCT include: improved travel time, reduced delay, fewer emissions, and fuel savings. In addition, an agency benefits through prolonged effectiveness of signal timing and reduced maintenance of traffic signal timing plans. The result is a substantial improvement that far outweighs the cost of the ASCT implementation. Despite these substantial benefits, ASCT deployments account for less than one percent of the existing traffic signal systems in the United States (2). In 2010, congestion in the United States cost $101 billion as a result of delay and extra fuel consumption (3). With such high costs due to congestion, ASCT is a promising alternative to improve traffic operations, given the high benefit to cost ratio and relatively low market saturation.

In 2010, congestion in the United States cost $101 billion as a result of delay and extra fuel consumption.

Why SynchroGreen?

SynchroGreen is a software-based ASCT implemented in the field, and simulated using Trafficware’s Synchro® and SimTraffic® software. Key functional characteristics of SynchroGreen are:

- Adjusts traffic signal timing in real time based on traffic demand.
- Utilizes three optimization engines to allocate green time and promote better traffic flow.
- Compatible with existing traffic control infrastructure, including many common traffic controllers and various forms of detection.
- Allows user selection of various strategies to facilitate balanced traffic flow, progression bandwidth, and critical movements.
- Adaptive traffic control seamlessly integrates with Synchro® and SimTraffic® for modeling and evaluating different system settings before deployment.
How does Synchro**Green** work?

SynchroGreen uses an agency’s existing traffic control infrastructure to provide real-time adaptive traffic control. The following sub-sections outline the system topology, algorithm, and modes of operation.

**Topology**

There are three major hardware components to any SynchroGreen system: the management system (server), local traffic controller(s), and vehicle detection. Within the SynchroGreen system, the server and local controller are commonly referred to as Signal System Master (SSM) and Signal System Local (SSL), respectively. A typical SynchroGreen setup consists of one SSM and several SSLs. There is no limit to the number of SSLs assigned to an SSM. The SSM is responsible for processing data and calculating updated timing plans. The SSL is responsible for gathering and buffering detection data, as well as executing the commands received from the SSM. The interaction between SSM and SSL is repeated every few seconds to ensure signal timings are always up-to-date.

SynchroGreen Central Server Software, which includes the interface, installs on the SSM as a Windows-based executable on the agency’s computer, while the SynchroGreen Intersection Software replaces prior controller software on each of the SSLs.

<table>
<thead>
<tr>
<th>SynchroGreen System</th>
<th>Signal System Master (SSM)</th>
<th>Signal System Local (SSL)</th>
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<tbody>
<tr>
<td><strong>Hardware</strong></td>
<td>Windows™ PC/Server</td>
<td>Approved Traffic Controller</td>
</tr>
<tr>
<td><strong>Software</strong></td>
<td>SynchroGreen Central Server Software</td>
<td>SynchroGreen Intersection Software</td>
</tr>
<tr>
<td><strong>Purpose</strong></td>
<td>Process data and calculate updated timing plans</td>
<td>Gather detector data and execute commands from SSM</td>
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Accurate vehicle detection is an important component of the SynchroGreen system. SynchroGreen detection consists of any reliable form of vehicle detection that delivers precise measurements of vehicle occupancy and traffic counts. Vehicle detection provides the input data upon which decisions are made within the SynchroGreen algo-
Algorithm

The primary objective of the SynchroGreen algorithm is to minimize total network delay, while providing reasonable mainline progression bandwidth. SynchroGreen utilizes three optimization engines designed to optimize the period (cycle length), phase allocation (splits), and start time (offsets) in real time based on current traffic conditions.
The primary objective of the SynchroGreen algorithm is to minimize total network delay, while providing reasonable mainline progression bandwidth.

Phase Allocation

The Phase Allocation is calculated for each phase every period that SynchroGreen is operational. The Phase Allocation is the adaptive counterpart of the phase split that is typically used under standard coordinated type of operation. The Phase Allocation calculation is based on the Green Utilization, or the duration of time that the phase is processing vehicles while at saturation flow. This is estimated using the stop bar detectors.

In addition to the Green Utilization, a Detector Calibration Factor is also used in the Phase Allocation calculation. The Detector Calibration Factor is used to calibrate detectors based on various sizes, positions, and prevailing vehicle speed over the detectors.

The Green Utilization and Detector Calibration Factor are used to calculate a Target Phase Allocation. The Target Phase Allocation is the amount of time each phase should receive under ideal circumstances; however, the Target Phase Allocation is not the final Phase Allocation that is sent to the controller. Before the final Phase Allocation is assigned, SynchroGreen must analyze the system globally, and must analyze every phase at every intersection.

Period

Once the Target Phase Allocation is calculated for every phase at each intersection, SynchroGreen analyzes the system globally. First, SynchroGreen sums the Target Phase Allocations and constructs standard ring-and-barrier diagrams; this establishes the Target Period at each intersection. SynchroGreen then looks at the system globally and selects the intersection with the highest demand as the critical intersection. The Target Period duration at the critical intersection is assigned to every intersection and the actual Phase Allocation is assigned to each phase based on the proportion of the Target Phase Allocation.

"Green Utilization is the duration of time that the phase is processing vehicles while at saturation flow."

"Saturation flow is the maximum flow rate through an intersection under prevailing traffic and roadway conditions."
Start Time

Start Time is the adaptive counterpart of the offset under standard coordinated traffic signal operations. Start Times are recalculated due to changes in the period duration as well as when traffic flow changes. The Start Time has two components: the lag time and the travel path. The lag time is essentially the relative offset from one intersection to the next and it is user-defined; however, it can be modified based on traffic flow characteristics. Advanced detectors allow for lag time modification based on the presence of queuing and the measured platoon arrival distribution. SynchroGreen detects the presence of queuing on mainline approaches. In this situation, SynchroGreen incrementally modifies the lag time such that the phase releases queues sooner and attempts to minimize the impact to oncoming platoons or groups of vehicles. SynchroGreen also establishes historical arrival distributions over time. If vehicles tend to arrive sooner or later than historical trends, the lag time will be incrementally modified to accommodate the platoons.
The last component of the start time is the travel path. The travel path is selected based on the predominant travel direction. The travel path can vary by time-of-day and instructs the algorithm when each of the SSLs should receive timing plans. This ensures that when a platoon arrives at an intersection, the SSL has the most recent timing plans so that coordination and progression are maintained. Common travel paths are shown below.

**Normal Path Selection**

Path 1

Int. 1
Int. 2
Int. 3
Int. 4
Int. 5

**Alternate Path Selection**

Path 1

Int. 1
Int. 2
Int. 3
Int. 4
Int. 5

Path 2

Path 3

*SynchroGreen allows the user to select up to four travel path configurations. The illustration above shows two typical travel path combinations utilized by current SynchroGreen customers.*

**Modes**

SynchroGreen allows an agency to customize the algorithm based on the goals and objectives of the project. By default, the SynchroGreen algorithm equitably distributes green time based on demand, while providing reasonable mainline bandwidth. However, traffic engineers may select different modes to promote mainline progression or critical movements. SynchroGreen modes are outlined as follows.
Benefits

SynchroGreen provides many benefits over other adaptive systems. SynchroGreen’s unique approach to adaptive control allows the agency to scale projects to meet their specific goals and budget requirements. Some of the major benefits of SynchroGreen are found on the following page.

[SynchroGreen’s unique approach to adaptive control allows the agency to scale projects to meet their specific goals and budget requirements.]

System Requirements

SynchroGreen uses as much of the agency’s existing infrastructure as possible. While it is not always possible to reuse the agency’s hardware, many times hardware can be inexpensively retro-fitted to satisfy SynchroGreen requirements. This section provides an overview of SynchroGreen requirements for traffic controllers, vehicle detection, and communications.
**Benefits of SynchroGreen**

- **Model Adaptive Operations Using Synchro® and SimTraffic®**
  SynchroGreen can model adaptive operations before deployment, allowing agencies to test and evaluate system settings.

- **Use Existing Infrastructure**
  SynchroGreen uses the agency’s existing traffic controllers and detection where possible, thus allowing agencies to use the hardware they already know.

- **Fail-Safe Operations**
  In the event SynchroGreen is deactivated, traffic controllers can revert to the time-of-day coordination plans.

- **Considers Side-Streets and Pedestrians**
  SynchroGreen considers side-streets and pedestrians, with no additional modules.

- **No Additional Proprietary Hardware**
  SynchroGreen does not require a “black box” to operate adaptively; it is a software-based adaptive signal control technology.

- **Use a Web-Based Interface to Control the System**
  The SynchroGreen web interface allows the user to monitor and control the system securely from an office or anywhere the agency has granted remote access.

- **Choose From Three Modes of Operation**
  The user can select SynchroGreen balanced, progression, or critical movement mode by time of day in order to minimize overall network delay, favor mainline bandwidth, or favor critical movements.
Traffic Controllers

SynchroGreen Intersection Software is designed to function on 2070 and ATC-type traffic controllers, and will operate on traffic controllers from multiple vendors. 2070 and ATC traffic controllers provide a powerful platform to run SynchroGreen and allow for expanded functionality in the future. The best way to find out if a traffic controller is compatible with SynchroGreen is to contact Trafficware directly or speak with an authorized SynchroGreen distributor.

SynchroGreen Simulation Lab

One of the benefits of SynchroGreen is the ability to test systems prior to field deployment. By using SimTraffic® to simulate SynchroGreen, Trafficware’s engineers are able to fine-tune key parameters, ensuring field deployment is a quick and efficient process. The same SynchroGreen Intersection software that is installed within a signal controller is used in SimTraffic®, by way of a Virtual Controller. The Virtual Controller, which will soon be available within Synchro®/SimTraffic®, will emulate the logic of an actual signal controller. Additional signal-related information is coded within the Virtual Controller through a series of menus. Each of the detectors coded within Synchro® are assigned channels based on the intersection’s signal phasing requirements, as they are in a real signal cabinet. As vehicles travel over the detectors, SynchroGreen collects occupancy and volume data, and calculates new timing plans. This process continues in “real time” during the simulation, just as it would if SynchroGreen were operating in the field. The use of SimTraffic® allows customers to visualize the benefits prior to installation and various measures of effectiveness can be summarized.
Detection

Proper vehicle detection is the key to an ASCT. SynchroGreen is no exception; detectors must be located in the correct positions and must be properly calibrated. Detection can be any non-proprietary technology (i.e., inductive loops, video, wireless, advanced radar, etc.) and multiple technologies can be used on the same system. SynchroGreen requires stop bar detection and advanced detection. Stop bar detectors must be placed on every lane, on every intersection approach; advanced detectors should only be placed on mainline through lanes, between 250 ft. and 500 ft. upstream of the stop bar. All detectors must be placed on independent channels. The user can adjust a detector calibration factor in order to account for the varying size, position, and sensitivity of different detectors. Furthermore, SynchroGreen contains logic that can minimize or eliminate erroneous detections and is also capable of notifying the user that a detector has failed.
Communications

SynchroGreen is an Ethernet-based system that can utilize many common communications technologies, such as fiber optic, wireless, cellular, or IP over copper. Each traffic controller is assigned a unique IP address and placed on the same network as the SynchroGreen Central Server. In the event of a minor communications failure, SynchroGreen will allow traffic controllers to operate using historical data and the system will remain online. Once communications are restored, the affected traffic controllers will resume normal SynchroGreen operations. If a catastrophic communications failure occurs, traffic controllers will revert to normally scheduled time-of-day operations.

Simulation

SynchroGreen uses a Software-in-the-Loop type of simulation to calibrate system settings and evaluate expected performance for each project. Synchro® is used to set up roadway geometrics, traffic flow characters, and driver behavior, whereas SimTraffic® provides the microscopic simulation environment. Instead of the default traffic signal logic in SimTraffic®, Trafficware's Virtual Controller and SynchroGreen Virtual Central Server are used. The Virtual Controller is a software module capable of reading actual intersection controller databases and emulating real traffic controller logic in SimTraffic®, while the SynchroGreen Virtual Central Server emulates the actual SynchroGreen server as it would perform in the field. Trafficware will provide a “Before” and “After” analysis to be reviewed by the agency before deployment.

SynchroGreen Candidate Projects

There are many applications for SynchroGreen where significant benefits can be realized. SynchroGreen is most beneficial where traffic patterns are not conducive to time-of-day signal coordination patterns, and where frequent and rapid fluctuations in traffic occur. The following characteristics are ideal for a SynchroGreen project:

- Random traffic patterns with frequent fluctuations in traffic volume and distribution of traffic.
- Traffic patterns are difficult to predict due to special events, diversions, or other situations that cannot be accounted for using standard traffic signal timing plans.
• Problems with coordination exist and are difficult to maintain due to pedestrians, emergency preemption, or the need for frequent pattern changes.
• Frequent signal retiming is required based on comments from the public or observed problems by engineering staff.
• Large queues on side streets exist and traffic on side streets is a major consideration.
• Pedestrian traffic is a major consideration.
• Mild to moderate oversaturation (congestion) occurs during peak periods
• Optimal signal timing plans are desired at all times.

Case Study: Brevard County

It is no secret that one of the best ways to reduce traffic congestion is through managing traffic flow and updating signal timing plans along signalized arterials. There are many benefits to using an ASCT, ranging from decreases in travel time to reductions in vehicle emissions. Agencies throughout Florida have traditionally been leaders in implementing the latest ITS (Intelligent Transportation Systems) strategies with this exact premise in mind. The Florida Department of Transportation (FDOT) and Brevard County are two such agencies that understand the importance of efficient traffic flow and the benefits that are attainable. The Brevard County Advanced Traffic Management System (ATMS) Expansion project includes several infrastructure enhancements, such as the installation of fiber optic communications, TS2 cabinets, detection hardware, central control software, as well as the deployment of SynchroGreen.

As one of the largest ASCT installations within the United States, this project includes almost 90 intersections operating along nine arterial roadways. Brevard County will have the ability to operate SynchroGreen and adjust signal timing at each of the intersections based on actual traffic demand. It is expected that overall signal timing will be vastly improved once SynchroGreen is installed, thus leading to a decrease in travel time, delay, and vehicle emissions. The project is expected to be complete by summer 2013.
Project Deployment

Typical SynchroGreen Implementation Timeline

1. Preliminary Assessment
2. Project Kickoff
3. Simulation
4. Verification
5. Pre-Implementation Meeting
6. Deployment
7. Adjustments
8. Evaluation
9. Post-Implementation Meeting
10. Training
11. System Acceptance
References


