The SCATS Adaptive Traffic System
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What is SCATS?

- SCATS = Sydney Coordinated Adaptive Traffic System
  - Originated in Sydney, Australia
  - Used in Europe, Australia, Hong Kong and some areas in the US (Oakland County, Michigan)
How does SCATS work?

- SCATS gathers data on traffic flows in real-time at each intersection.
- Data is fed via the traffic controller to a central computer.
- The computer makes incremental adjustments to traffic signal timings based on minute by minute changes in traffic flow at each intersection.
SCATS Functions

- Detects traffic volume by movement
- Converts data to flow rate
- Calculates optimal cycle length
- Calculates optimal splits by phase
- Determines phase combinations
- Checks timing alteration thresholds
- Sets up implementation
SCATS Architecture

Management Functions

Central Management System

Strategic Traffic Control

Regional Computer

Traffic Controllers - Tactical Traffic Control

Regional Computer

Regional Computer

Regional Computer

Regional Computer

1 to 32

up to 250 per Regional Computer
SCATS Architecture

- Central Computer – Communications and Database Functions
- Regional Computer – Strategic Control
- Local Traffic Controllers – Tactical Control
SCATS Architecture

1. Central Computer
   - Only for centralized monitoring of system performance and equipment status.
   - Central monitor computer (CMS)
     (a) data collection, input and monitoring
     (b) connected with Management Computer
   - Management computer: printer terminal, visual display, PC work Station.
   - To maintain system at minimum resource owing to central management.
   - To diagnose faults quickly
2. Regional Computer

- It maintains autonomous traffic control of a set of controllers.
- The system is expandable by simply adding regional computers.
- To perform the strategy control algorithm.
- To use the time-of-day and traffic information to select green split plan, interval offset plan and cycle time.
SCATS Architecture

2. Regional Computer

- The local controller within region are grouped into systems and subsystems.

(a) System:
* It was divided by typically geographically unrelated.
* They do not interact with each other.

(b) Sub-System:
* The basic element of control at the strategic level.
* Each sub-system may comprise one to ten intersections.
3. Local Controller

- For strategic operations, passes information to regional computer and accepted information to adaptive traffic condition.

- For tactical operations:
  (a) operate under the strategic umbrella.
  (b) keep local flexibility to meet cyclic variation in demand at each intersection.
  (c) base on detector information.
SCATS Hardware

- Management Computer – DEC VAX/ALPHA, Pone VMS

- Regional Computer – Personal Computer with Windows NT and Digi serial communications interface modules.

- Local Processor – Traffic Controller with SCATS functionality.
SCATS Controllers

- 170 E Controllers Thru Interface Card
- 2070s Thru Controller Software
- ATC Controllers
SCATS Sensors

- SCATS operated by looking at “Space” between vehicles.
- There is a relationship between traffic density and Space time.
- Degree of Saturation – measure of effectiveness of green time.
• Loop detectors or Video detectors (as used in Oakland County, MI) in most lanes at the stop line.
Communication Philosophy (1)
Adaptive Control

1. Strategy control
   It is undertaken by the regional computers

2. Tactical Control
   It is undertaken by the local controller
(1) General Concept

- Basically, it concerned with the selection of suitable signal timings for the target area and sub-areas based on average prevailing traffic conditions.

- The detection information are preprocessed in the controller and sent to a regional computer to calculate “DS.

- The algorithm is applied at a cycle-by-cycle basis.

- The phase split plan, internal offset plan, external offset plan and cycle length are applied to the sub-system for the next cycle.
Strategic Control

The Algorithms:

- (1) Degree of Saturation (DS)
- (2) Car Equivalent Flow
- (3) Cycle Length
- (4) Green split Plan
- (5) Offset Plans
- (6) Linking of Sub-systems
Degree of Saturation

$$DS = \frac{g'}{g} \quad g' = g - (T - th)$$

DS = \frac{\text{green-(unused green)}}{\text{available green}}

Where,
- DS - Degree of saturation;
- g - the available green time;
- T - the total space time (no vehicle pass the sensor);
- t - the unit space time between vehicles while discharging (caused by the distance between vehicles);
- h - the number of spaces;
Degree of Saturation

- Unused green is a measure of efficiency (0 at saturation flow, + for under saturation, - at oversaturation).
- Standard space time at the maximum flow is self calibrated daily.
- DS is the ratio of efficiently used phase time to available phase time.
- DS can be >100%. i.e., during oversaturation, the used green can be negative – vehicles are closer than standard space time at the maximum flow.
If the DS of main (side) road reach 90%, add green time to main(side) road and reduce green time of side (main) road.

If the DS of both main and side road reach 90%
Car Equivalent Flow (VK)

- Derived from DS and the lane saturation flow for each lane;
- Independent of Vehicle types in traffic stream;
- The Car Equivalent Flow is calculated from the “measured DS”, Maximum flow rate for each strategic detector.

\[ VK = \frac{DS \cdot g \cdot S}{3600} \]

VK = DS * Green Time * vehicles per second at maximum flow;
Cycle Length

- Delay increases rapidly for CL below Co (optimum CL)
- Exact CL not critical as long as not less than Co
- SCATS Subsystem CL determined from highest value of DS in the subsystem.
Cycle Length

- All intersections within a sub-system operate on a common cycle length.

- The Cycle Length is a function of the highest DS measured in the sub-system of the previous cycle.

- User defined equilibrium DS values used to determine relationship between measured DS and CL.

- The target CL is determined by measured DS.
Cycle Length

- Define RL’ as the difference of RL(current revised CL) and last CL to record the moving direction of optimal CL.

- Weighted average of RL’ (last three cycles) determine the final RL.

- CL can move toward final RL by +/- 6 secs.

- CL can move up to 9 secs if RL’ for the last two cycles was > 6 secs. (allows response to steep change in demand)
Cycle Length

- There are four background cycle length:
  - Cmax: maximum cycle length
  - Cmin: minimum cycle length
  - Cs: a medium cycle at which good two-way coordination can be achieved:
  - Cx: all additional cycle length is given to a nominated phase. It was selected by the strategic detectors data.
- Note: subsystems at Cmin move to Cs unless the detected flow is lower than the scheduled limit.
Split Plan

- Four background split plans are provided to face different traffic condition.
- The split plan also specified the normal sequence of phases.
- Possible plans are examined each cycle to determine the most “equisat” plan for the next cycle.
- Equisat: DS on critical approaches equal.
- The new plan is determined while 3 of 4 votes (decision in each cycle) is the same.
Each cycle make a decision:
- If 3 of 4 decisions from 4 successive cycle is the same, change the split plan;
- Otherwise, keep the same split;
Offset Selection

- The offset is independent of cycle length and green split variation.

- It may be defined as function of cycle length to allow for queuing or link speed changes during heavy traffic.
  (a) shorten: to allow for increasing residual queuing as demand rises.
  (b) lengthen: to reflect the lower platoon spreads occurring in heaving traffic condition
Offset Selection

- The magnitude and direction of offset alteration is specified by the value and sign of $A$.
  
  $$P' = P[1 + A \cdot g(C)]$$
  
  - $P'$: the modified offset;
  - $P$: the basic offset;
  - $A$: the specified modifying factor (+/-);
  - $g(C)$: linear function of cycle length; $g(C_{\text{max}})=0$; $g(C)=1(C < 0.75C_{\text{max}})$. 
Offset Selection

- The five offset plans: plan 1 operates only at $C_{\text{min}}$, plan 2 only operates at $C_s < C < C_s + 10$. The remaining three are selected by a voting algorithm based on VK.
- Offset plan vote is calculated once per cycle.
- The same plan from 4 of 5 votes is the new plan.
Linking of sub-systems

SCATS uses an index to decide the combination of sub-systems (SS):

- If the difference of Cycle Length at adjacent is less than 9s, the index +1;
- If the index = 4, the SSs should be combined as a new SS. The new Cycle length is set as the largest one of the original SSs.
Algorithm Subsystem Linkage

Decide Link or Not

Criteria Comparison

Benefit
- Linking

No Benefit
- Not Linking

Select 5 External Plan Based On Direction And Volume Between Sub-System

Linking Implement Condition Merit Spread
Regional Computer

External Offset 5 Plan

Criteria Comparison Cycle by cycle

Favor (+) Increment

Favor (+) Increment

Linkage 4: from 0:break

Nominate Cycle Length

Others Adjust Following

Appropriate Offset

Permanent Linkage

Force Immediate Linkage

Select Link Plan

Plan
Tactical Control

- This level of control is undertaken by the local controller.

- The tactical control is able to modify the signal operation by strategic control.

- Note: The main road phase can not be skipped or terminated early to own the signal co-ordination in tactical control.
Tactical Control

Any phase may be
(a) terminated early when demand is smaller than average demand
(b) omitted entirely when on demand
(c) continued to its maximum value

The local controller bases on tactical decision by information from the vehicle detector at the intersection.
Local Controller Functions

- 1. Mode of Operation
- 2. Phase Timing
- 3. Detector Logic
Conditional demand, locking, unlocking, turn left on red

Manual Override

Input
computer time plan; 24 detector; 8 pedestrian

Microprocessor controller
Operation Models

Field terminal portable pc

Output
16 veh. Signal group; 8 pedestrian Signal group

flashing
Fault; lamp switch interlock; electronic conflict; any safety concern

flexilink
No computer information; cableless coordination; alter-RAM; prepare 10,16 or 20 plan; preset operate; FLEXIGEN generate, via CMS download

masterlink
Control: regional computer; can operate actuate timer; coordination; varied pedestrian. Signal to match prevail traffic; constrained by local controller safety design

Sister/vp
Overlap veh. And pedestrian Group green flexibility; independent of phase boundary; depend on any conceivable string of condition

isololate
Gap; waste; maximum; minimum; late start; rest 150 sec.; yellow; all red; pedestrian 0-40; clearance 1; clearance 2.
Mode of Operations

(1) Masterlink mode

- The controller operates in a coordinated system under the control of a regional computer.
- To use the strategic data:
  - (a) approaching volume counts
  - (b) total loop operation time during green time
- The controller receives the split plan offset plan and cycle time to be implemented.
- To change stage away from a main road, permission is required from a regional computer.
- A side street can be gaped out when successive vehicles are greater than 5 seconds and return unused green to the main road.
- It can skip to a nominated stage when there is no demand.
Mode of Operations

(2) Flexilink mode

- It performs the coordination when Masterlink fails to link to a central computer.
- To operate at preset times and selected plan by TOD.
- It can be used independently of a Masterlink system.
- It is a cableless linking.
(3) Sister/VP link mode

- A pedestrian Phase includes: Pedestrian Walk interval and Pedestrian Clearance interval;

- A Vehicle Actuation (AP) Timer allows for the early termination of any phase;

- The sister/VP link model is to coordinate the signal between a vehicle actuated controller and a pedestrian controller.
Mode of Operations

- **(4) Isolated Model**
  - To operate at isolated fixed time, isolate semi or full actuated control.
  - To specify time-setting: phase sequence, maximum duration, gap out, omitted, waste time.

- **(5) Flash mode**
  - To flash yellow or red/yellow display
  - To work as control sequence fault, lamp switching interlocking circuitry, electronic conflict monitoring.
  - A kind of safety design,
  - Safety interval time can not be altered in “RAM”.


Phasing Timing

- The time setting are stored in “PROM”, but alternative (overriding) time settings may be stored in “RAM”.

- RAM:
  - (a) long life battery to maintain its content.
  - (b) alter from keypad on the controller or from a SCATS terminal.
Phasing Time

- (1) vehicle phase intervals
  - Late start green: 0 to 20 seconds
  - Minimum green: 0 to 20 seconds
  - Reset green: 0 to 150 seconds
  - Yellow: 3 to 6.4 seconds
  - All red: 0 to 15 seconds.
(2) Pedestrian phase intervals

- Pedestrian walk interval (0-40): display isolated or minimum walk time in Flexilink and Master link.

- Pedestrian clearance 1 interval (0-40): flashing before any vehicle signal can step to yellow.

- Pedestrian clearance 2 interval (0-40): flashing with vehicle yellow and all red.
Phasing Time

- (3) Vehicle actuation timers
  - **Gap change**: time between successive actuates of detectors exceeds a preset value (3-5 sec.)
  - **Waste time change**: accumulates (preset headway - detectors actuation) until waste time over preset value (6-10)
  - **Maximum change**:
    - (a) in the case of isolated control mode, each phase has been set with a Max time.
    - (b) in the case of Masterlink mode: the maximum timer does not operate and the phase is terminated by a command from the regional computer
    - (c) in the case of Flexilink mode: the point of terminating the phase is determined by the current plan.
Detector Logic

- (1) to work as different roles as defining in each control mode.
- (2) Locking demand: once place, it remains even if detector does not sustain an output.
- (3) Non-locking demand: cancel of detector output indicates the vehicle has left.
- (4) The logic is used for the introduction of a phase which services a filtering right turn movement or a unprotected left-turn movement.
Deficiencies of SCATS

- With the stopline detection philosophy, it is impossible to provide currently feedback information about the performance of signal progression.

- There is no traffic model in SCATS, the “adaptive” process is completed by the local actual control, which limits the use of an optimization methodology.
References

Introductions


References

Algorithm and Functions


References

Presentations by the Company


References

Evaluation and Application

