Chapter 40

Area Traffic Control

40.1 Introduction

ATC systems are intelligent real-time dynamic traffic control systems which are designed to effectively respond to rapid variations in dynamic traffic conditions. It is an advanced process to control the traffic. It is a traffic responsive system that use data from vehicle detectors and optimize traffic signal time in real time. The timing plan of traffic controllers changed automatically. The technique employs digital computers for achieving the desired objective.

40.2 Basic principles

The basic system Originally, it was assumed that the power of the digital computer could be used to control many traffic signals from one location, allowing the development of control plans. The basic concept can be summarized thus: the computer sends out signals along one or more arterial. There is no feedback of information from detectors in the field, and the traffic-signal plans are not responsive to actual traffic conditions. Earlier,the plans for such a system are developed based on the engineers usage of data from field studies to generate plans either by hand, or by computer,using packages available at the time. The computer solutions were then run on another machine, or in off hours on the control computer when it was not being used for control of the traffic signals. Though this "*off-line*" system of control plans gives an image of a deficient system, there are many advantages of this "*limited*" system. These include:

1. Ability to update signals from a Central Location: The ability to retime signals from a central location without having to send people along an entire arterial to retime the signals individually at each intersection saves lot of time.

2. Ability to have multiple plans and special plans: In many localities a three-dial controller is quite sufficient: if traffic is generally regular, three basic plans (A.M. peak, P.M. peak,

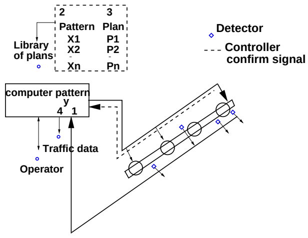

Figure 40:1: Computer control system with detector information used

off-peak) can meet the needs. The computer opens the possibility to have an N-dial controller, with special plans stored for certain days. With appropriate plans stored for each such event, the plans can be called up by time of day, or by operator intervention.

3. Information on equipment failures: The early systems simply took control of electro-mechanical controllers, driving the cam-shaft from the central computer and receiving a confirmation signal. Failure to receive this signal meant trouble. The information provided by the control computer allowed such failures to be detected and repair crews dispatched.

4. Performance data on contractor or service personnel: With a failure detected and notification made, the system can log the arrival of the crew and/or the time at which the intersection is returned to active service.

Collection of traffic data The ability of a computer to receive great amount of data and process it is made use of by detectors in the field for sending information back to the central location. If the information is not being used in an "*online*" setting and hence still does not influence the current plan selection. Typically, the computer is being used as the tool for the collection of permanent or long-term count data.

Traffic data used for plan selection Fig. 40:1 shows a computer control system that actually uses the traffic data to aid in plan selection. This can be done in one of three principal ways:
1. Use library - Monitor deviations from expected pattern: This concept uses a time-of-day approach, looking up in a library both the expected traffic pattern and the preselected plan matched to the pattern. The actual traffic pattern can be compared to the expected, and if a deviation occurs, the computer can then look through its library for a closer match and use the appropriate plan.
2. Use library - Match plan to pattern: This is a variation on the first concept, with the observed

pattern being matched to the most appropriate pre-stored pattern and the corresponding plan being used.
3. Develop plan on-line: This concept depends on the ability to do the necessary computations within a deadline either as a background task or on a companion computer dedicated to such a computations. This approach presumes an advantage to tailoring the control plan to specific traffic data.
It is necessary to note that the time between plan updates is constrained by the speed with which the on-line plan computations can be done. The desire to have more frequent updates implicitly assumes that the real traffic situation can be known precisely enough to differentiate between consecutive update periods.

40.2.1 Advantages

The various Advantages of an area traffic control system are

- **Minimizing journey time for vehicles-** Are traffic control system minimize the overall journey time by reducing the no of stop delays, increasing the average travel speed etc.
- **Reducing accidents-** Are traffic control system reduces the no of accident by reducing the congestion as congestion is less the traffic flow will be smooth so accident also will be less.
- **Increasing average saving in fuel-** As we discussed above that it will minimize the journey time, accident, congestion, stop delays so we can easily say that average saving in fuel will increase and traffic flow also will be safe and smooth.

40.2.2 Disadvantages

The various disadvantages of an area traffic control system are

- **Very costly-** Area traffic control is a very advanced traffic control strategy it involve very advanced technology and highly skilled persons to operate the system to control the traffic which makes it very costly.
- **Very complex-** Area traffic control system is a very big system which includes many unites in it like Vehicle Detectors, Intersection Controller, Communication Network, Application Software, Central (Regional) Control System. These unit is use to perform different-different task for the system. These unit and task make it very complex.

- **Suitable only for lane following traffic-** In area traffic control system we use vehicle detector to collect the data to find the actual flow and to get signal timing according to the present condition of traffic. These vehicle detectors detect the vehicle on the basis of lane. For example we are collecting data for tow lane road then the detectors will able to detect the vehicle which will come from their respective lane and the vehicle which is using space other than these two lanes cannot be detected. So data will not be accurate. So we can say that it will give best result only for lane following traffic.

40.3 Major Building Blocks of ATC

Major Building blocks of the Area Traffic Control Systems are: Vehicle Detectors, Intersection Controller, Communication Network, Application Software and Central (Regional) Control System which are described below:

40.3.1 Vehicle Detectors (VD)

Vehicle Detectors is used to detect the presence of vehicles, to collect data to find average speed, vehicle flow, vehicle density, queue length measurement. VD acts as a nodal point between vehicle and intersection controller. Detector could be of various types example-ultrasonic, microwave radar, infrared laser radar, non-imaging passive infrared, video imaging, acoustic array, magnetic loop Inductive loop vehicle detector is commonly used. Fig. 40:2 is showing example of Vehicle Detectors. In Fig. 40:2 two detectors are shown, 1 is for straight going traffic which will detect the vehicle which will go straight and 2 is right turning traffic which will detect the vehicle which will take right turn from there.

40.3.2 Intersection Controller

It is the micro-macro computer. It placed at intersection for temporary storage of data. It collects the data from vehicle detector and sends it to the central control. Central control processed the data and sends it back to the intersection controller which then implements the signal timings as instructed at the intersection. Intersection controller for each set of traffic signals receives the signal states from the control system.

40.3.3 Communication Network

The communication network transfers data from the signal controller, to the central control station where optimized signal timings and phases are determined and it again transfers in-

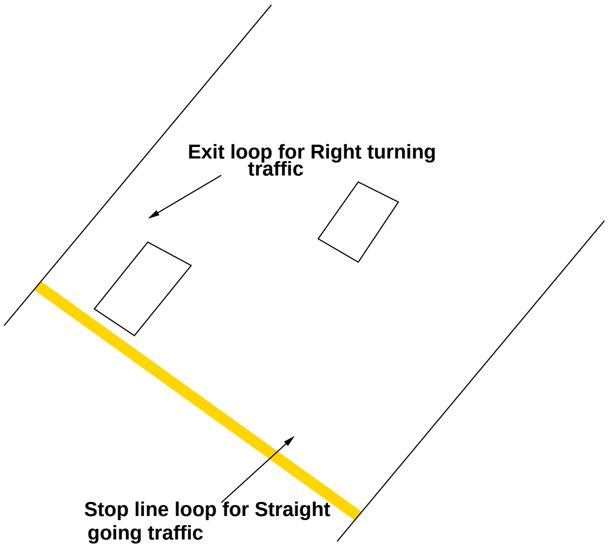

Figure 40:2: Example of Vehicle Detectors (Source Muralidharan, 2006)

formation to the signal controller as per the data processed. It transfers the data obtained from detectors to central control which then implements the signal timings as instructed at the intersection. Fig. 40:3 is showing the communication network.

40.3.4 Application Software

Application software is the software used behind the whole ATC system which performs the entire task. It is a large and complex program involving multiple systems, various procedures for implementation. Functions of Application software are: It defines the architecture flows, activities and functions and user services that planners want to deliver.

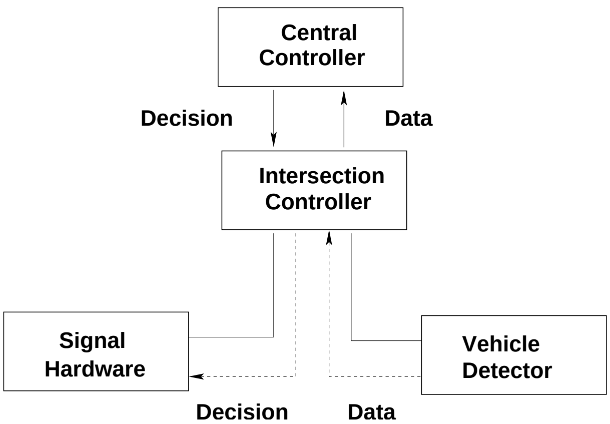

Figure 40:3: Communication Network (Source: Muralidharan, 2006)

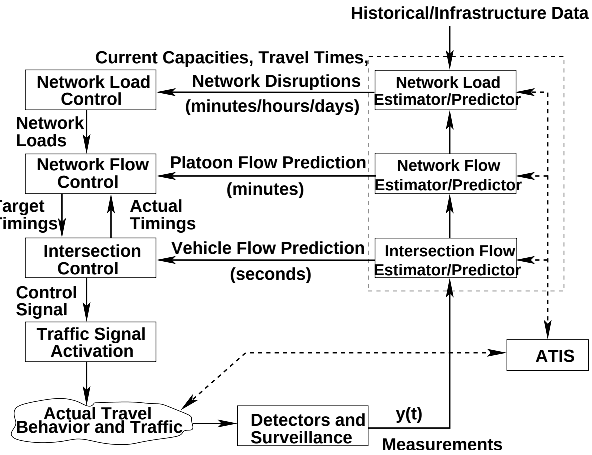

Figure 40:4: Area traffic control architecture (Source: Pitu B. Mirchandani, K. Larry Head,1998)

40.3.5 Central Control System

It is the main unit of ATC. In this unit collected traffic data is processed to optimize various traffic parameters like-signal timing, phase change, delay Important and major task of ATC system is performed by this unit. It supervises all the units of ATC.

40.4 Architecture of (ATC)

Fig. 40:4 is showing the arrangement of whole area traffic control system with all units of the system. These unites will be use for different-different task in the system. It could we described in three stages. At first stage estimation of is done, it is done based on the slow-varying characteristics of the network traffic load in terms of vehicle per hour than according to this estimated ATCS allow to allocate green time for each different demand for each phase. At the middle stage traffic characteristic are measured in terms of platoons of vehicle and their speeds and at last stage intersection controller select the suitable phase change based on observed and predicted arrivals of individual vehicle at each intersection.

40.5 Operational models

An operating model is the abstract representation of how an System operates across process. Any system is a complex system consisting of several different interlinked logical components. An operating model breaks this complexity into its logical components in order to deliver better value. Some examples of operational models are SCOOT, SCAT and OPAC which are described below.

40.5.1 SCOOT (Split Cycle Offset Optimization Technique)

The Split Cycle Offset Optimization Technique (SCOOT) is an urban traffic control system developed by the Transport Research Laboratory (TRL) in collaboration with the UK traffic systems industry. It is an adaptive system which responds automatically to traffic fluctuations. Prime objective of this is to minimize the sum of the average queues in the area. It is an elastic coordination plan that can be stretched or shrunk to match the latest traffic situation. Continuously measures traffic volumes on all approaches of intersections in the network and changes the signal timings to minimize a Performance Index (PI) which is a composite measure of delay, queue length and stops in the network. Each SCOOT cell is able to control up to 60 junctions. Handling input data up to 256 vehicle counting detectors on street. Detectors are usually positioned 14 m behind the stop line.

Principles of SCOOT

1. Cycle Flow Profiles (CFP) measure in real time
2. Update an on-line model of queues continuously
3. Incremental optimization of signal settings

1. **Cyclic Flow Profiles (CFP)**
   CFP is a measure of the average one-way flow of vehicles passed at any point on the road during each part of the cycle time of the upstream signal. It records the platoon of vehicles successively within a cycle time during peak flow. It updated in every 4 seconds. CFPs can be measured easily by hand. Shape of the CFP has to be calculated for each one-way flow along all streets in the area. Accuracy of calculation depends on the accuracy of the data on average Flows, saturation flows, and cruise times.
2. **Queue Estimation**
   It is necessary to predict new signal timing due to the queues after alteration according to the situation after knowing CFP, the computer can be programmed to estimate no of vehicles which will reach the downstream signals during red phase. So size of the queue and duration to clear the queue can be calculated. In this calculation it is assumed that the traffic platoons travel at a known cruising speed with some dispersion. Queues

discharge during the green time at a saturation flow rate that is known and constant for each signal stop line.

3. **Incremental Optimization**
   Incremental Optimization is done to measure the coordination plan that it is able to respond to new traffic situations in a series of frequent, but small, increments. It is necessary because research shows that prediction of traffic flow is very difficult for next few minutes. SCOOT split optimizer calculates whether it is good to advance or retard the scheduled change by up to 4 s, or to leave it unaltered. It is achieved by split optimization, offset optimization, cycle time.

   (a) **Split Optimizer**
   Works at every change of stage by analyzing the current red and green timings to determine whether the stage change time should be advanced, retarded or remain the same. Works in increments of 1 to 4 seconds.

   (b) **Cycle Time Optimizer**
   It operates on a region basis once every five minutes, or every two and a half minutes. Identifies the "critical node" within the region and will attempt to adjust the cycle time to maintain this node with 90% link saturation on each stage. It can increase or decrease the cycle time in 4, 8 or 16 second increments according to the current requirement of the traffic flow.

   (c) **Offset Optimizer**
   It works once per cycle for each node. It operates by analyzing the current situation at each node using the cyclic flow profiles predicted for each of the links with up-stream or downstream nodes. It assesses whether the existing action time should be advanced, retarded or remains the same in 4 second increments. Fig. 40:5 is showing the key elements of the SCOOT ATC system which we described in above points.

Working Principle of SCOOT

Scoot system consists of a number of SCOOT cells or computers, each cell can control up to 60 junctions and handling input data from up to 256 vehicle counting detectors on street. SCOOT detectors are placed at 14 m from the stop-line, from the approach to the junction as possible. Fig. 40:6 clearly shows the working principle of SCOOT where the detectors placed upstream sense the occupancy and the information is transmitted to the central computer. SCOOT traffic model and optimizers use this information to calculate signal timings to achieve the best overall compromise for coordination along all links in the SCOOT area. The main aim

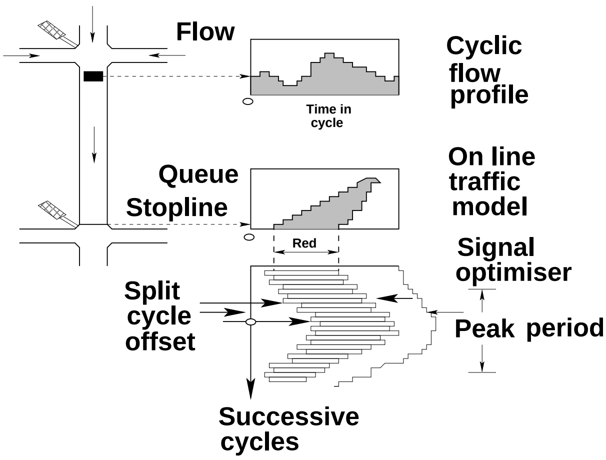

Figure 40:5: Key elements of the SCOOT ATC system (Source: Dennis I. Robertson and R. David Bretherton 1991)

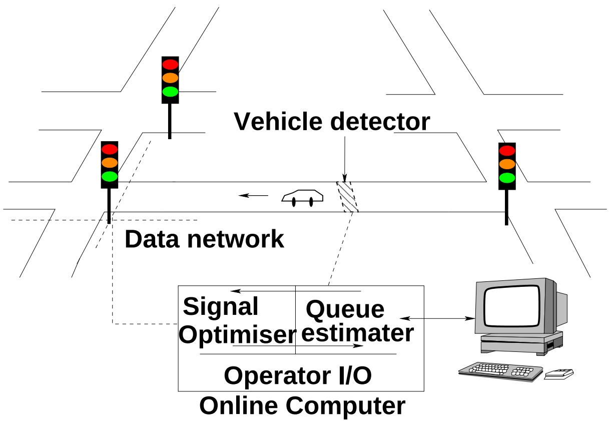

Figure 40:6: Working Principle of SCOOT (Source: www.scoot-utc.com)

of the SCOOT traffic signal control system is to react to changes in observed average traffic demands by making frequent, but small, adjustments to the signal cycle time, green allocation, and offset of every controlled intersection. For each coordinated area, the system evaluates every 5 minutes, or 2.5 minutes if appropriate, whether the common cycle time in operation at all intersections within the area should be changed to keep the degree of saturation of the most heavily loaded intersection at or below 90%. In normal operation SCOOT estimates whether any advantage is to be gained by altering the timings. Fig. 40:6 is showing the working principle of SCOOT. From above fig we can have an idea that vehicle will be detected with the help of vehicle detector. The collected data will be send to intersection controller after that it will be send to the central controller with the help of communication network. There it will be use to estimate the signal timing according to the actual traffic flow needs. Then the central controller will send the signal timing to the intersection controller to implement.

Features of SCOOT

1. **Variable Message Signs**
   Scoot display message signs to convey the guidance to the driver which is very helpful for the drive.

2. **Diversions**
   This feature is provided to deal with any emergency situation for example if any problem is found out in any lane which is found out with the help of Fault Identification & Management unit then traffic will be diverted from that lane to another lane.

3. **Emergency Green Wave Routes**
   This feature is provided to deal with any hazardous situation.

4. **Fixed Time Plan**
   This plan is applied when any unit of ATCS stopped working so till the time that unit starts functioning.

Limitations

1. Inability to handle closely spaced signals due to its particular detection configuration requirements, its require some time to detect vehicle.

2. Interface is difficult to handle, as this is highly technical so difficult to understand and handle.

3. Traffic terminologies are different from those used in India.

4. Primarily designed to react to long-term, slow variations in traffic demand, and not to short-term random fluctuations.

40.5.2 SCAT (Sydney Coordinated Adaptive Traffic)

SCAT (Sydney Co-ordinated Adaptive Traffic Control) System was developed by the Roads and Traffic Authority (RTA) of New South Wales, Australia in the late 1970s. It is automated, real time, traffic responsive signal control strategy. Timing of signals is governed by computer-based control logic. It has ability to modify signal timings on a cycle-by-cycle basis using traffic flow information collected at the intersection approach stop lines. It is not model based but

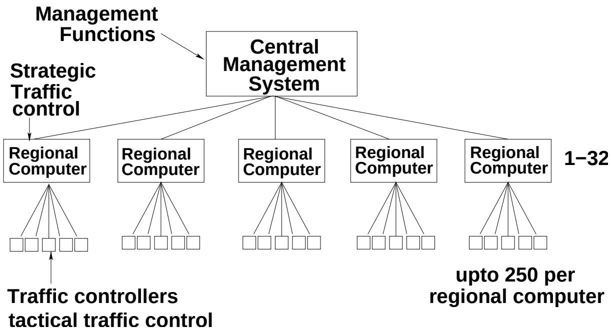

Figure 40:7: Shows the SCAT Computer Hierarchy (Source: Lowrie, 1982)

has a library of plans that it selects from and therefore banks extensively on available traffic data.

Working Principle

The system is very flexible, powerful, expandable, and yields unprecedented monitoring and management possibilities. The total system is divided into intersection, regional and a central system management. Distribution of the regional computers is determined by the economics of communication. Each regional computer maintains autonomous control of its region. Input data is collected by a system of traffic sensors. Sensors may be inductive loop detectors embedded in the pavement or video image devices mounted overhead on the signal strain poles. The system is designed to auto calibrate itself according to the data received, to minimize the need for manual calibration and adjustment. Fig. 40:7 shows the SCAT Computer Hierarchy.

It supports four modes of operations

1. Normal Mode- Provide integrated traffic responsive operation
2. Fall-Back Mode- Implement the time plans when computer or communication failure occurs
3. Isolated Control Mode- vehicle actuation with isolated control works
4. Fourth mode- signal display flashing yellow or red at all approaches

Benefits of SCAT

1. Travel time and accident reduction, saving in fuel consumption, and reduces air pollution.

2. It replaces the manual collection of data which are required for road Planning.

3. It provides a greater volume of original data with good accuracy level.

Limitations

1. Lacks user-friendly interface features to support day-to-day operations & programming tasks.

2. The error messages are not easy to read & do not provide the opportunity for corrective actions by system operators.

3. It is expensive because it includes advanced technology which is expensive and to understand and operate this type of technology person should have very good knowledge.

40.5.3 OPAC (Optimized Policies for Adaptive Control)

It is developed by Parsons Brinkerhoff Farradyne Inc. and the University of Massachusetts at Lowell jointly. It is a distributed traffic signal control strategy. The network is divided into sub-networks, which are considered independently for optimization purpose. OPAC breaks between two models: one for congested networks and the other for uncongested networks.

Feature of OPAC

1. Signal timing is calculated by dynamic optimization algorithm to minimize total intersection delay and stop.

2. Algorithm uses measured and modeled demand to determine phase distribution at each signal that are constrained by minimum and maximum green time.

Principles behind development of OPAC strategy

1. It must provide better performance than off line methods

2. It should be totally demand responsive. It means to adapt to actual fluctuating traffic condition

3. It must not be restricted to any fixed control period (e.g. 10 min)

Limitation

1. It is based on the pseudo dynamic programming technique, so it finds result near to optimal but not exactly optimal.

2. Its performance varies with traffic saturation condition. Better in under saturated traffic conditions.

3. It is expensive because it includes advanced technology which is expensive and to understand and operate this type of technology person should have very good knowledge.

40.6 Conclusion

Area traffic control system can reduce traffic delays, fuel consumption, accident, congestion, travel time, environmental pollution substantially and can increase average flow speed. Regarding ATC systems, SCOOT, SCAT and OPAC are popular in advanced countries but such systems cannot cope up with Indian situations because in India traffic is not lane following, highly mixed traffic, uncontrolled side road and on-street parking, Data loss due to power failure and Availability of funds.

40.7 References

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