Automated Traffic Signal Controller with Remote Accessibility

Dr. JAKS Jayasinghe, B.Sc. (Eng.), M.E.E., Ph.D., MIEEE
H. Kodikara Arachchi, B.Sc. (Eng.)

Automated Traffic Signal Controller with Remote Accessibility

Dr. JAKS Jayasinghe, B.Sc. (Eng.), M.E.E., Ph.D., MIEEE
H. Kodikara Arachchi, B.Sc. (Eng.)

Abstract

Development of the hardware, firmware and control and monitoring software to interface the UNIROAD Traffic Signal Controller (TSC) to Advanced Traffic Control System (ATCS) is described. This system is capable of controlling and monitoring traffic signal controllers over a standard telephone link. It is specially developed at a low cost for third world countries such as Sri Lanka.

1. Introduction

Increase in vehicular traffic density in a city, results in a variety of problems including economic, social and environmental problems. Presently, Colombo and sub-urban areas, highly populated and highly commercialized areas of Sri Lanka, are hard hit by these problems. Even though solving traffic problems, which is fatal in several aspects is a necessity, developing countries such as Sri Lanka cannot immediately invest in solutions of wide roads, properly designed junctions, subways etc. As an immediate solution, traffic management system can be effectively used in order to minimize the problems related to increased vehicular traffic density. An integral part of any traffic management system is a Color Light System (CLS). Independently operating CLS at junctions in close vicinity may make the problem worse unless the CLS at every junction is operated in a coordinated manner. In a properly coordinated CLS system, green time for heavy traffic routes are adaptively updated according to traffic flow and junctions in close proximity are synchronized with each other such that motorists can pass several junctions at a stretch [4 and 7]. This paper describes the hardware and software developments as an add-on module for the existing UNIROAD traffic signal controller developed at University of Moratuwa [6] for supporting a coordinated environment under the new ATCS (Advanced Traffic Controlling System) concept.

The major requirement of a adaptive coordinated CLS system is the ability to synchronize one CLS with other CLSs with the ability to adapt itself to emergency requirements. For example if a road is closed, the traffic flow changes. In order to cope with such a situation effectively, all CLSs should change their timing plans while maintaining the synchronism. Synchronization and adaptive modification of timing of CLS can be implemented by establishing communication links from a control center to each CLS. To simplify operation of the control center, the CLSs are operated on a cluster basis. A cluster is a set of junctions in close proximity in which the CLSs are operated in synchronism. Assignment of member CLS to a cluster is not permanent because there may be situations where those assignments should be changed according to traffic flow patterns.

1.1. SYSTEM ARCHITECTURE OF ATCS

The research work reported in this paper is based on the Advanced Traffic Control System (ATCS) depicted in Fig. 1. It provides following sub-systems.

1. Coordinated color light system
2. Variable message sign system
3. CCTV based traffic flow parameter extraction and monitoring system
4. Intelligent traffic information system

CCTV cameras are mounted at several strategic locations including signalized junctions. The images produced by those cameras are used for extracting vehicular flow parameters, monitor traffic congestion and other monitoring purposes. The vehicular flow parameters are extracted by image processing techniques. These image processors are located at the camera site when image is not required for other monitoring purposes. When images are used for vehicular flow parameter extraction and other monitoring techniques, images are transmitted to the central control room and process them for required parameters. Traffic flow parameters extracted are fed to the flow-model that calculates traffic plans for each TSC. The flow model is a multi-processor-based algorithm executed on distributed computer network. The architecture is fully described in [5]. The traffic plans calculated by the flow-model are downloaded to the appropriate TSC from the Control Center (CC) via communication controller (ComC). Work represented here describes the hardware, software and firmware aspects of implementing the flow model and related modules.

2. COMMUNICATION STANDARDS AND TCPIP INSTRUCTION SET

In order to support the ATCS system described above, the following communication standard is adopted for the communication between TSC and the CC. The data and control instructions are grouped into packets of 8-bit binary data. Idle RQ technique [2] is adapted for error controlling. Packet size of the Uplink (from CC to TSC) is 35-byte and that of the Downlink (from TSC to CC) is 36-byte. Packet structures are shown in Fig. 2. The packet is filled with TCPIP (Traffic Control Processor Inter-process Protocol) instructions and related data as shown in Fig. 3. If the size of instructions and related data is less than the specified packet size, the first unrelated byte is set to zero to mark the end of valid data in the packet.

The Upload packet consists of one or more TCPIP instructions to the TSC. Usually the Download data packet is composed of replies to each TCPIP instruction in the Upload packet, except for special requests from the TSC. Download instructions may be status instructions or reply instructions depending on the instruction for which it replies. The formats of the Upload and Download TCPIP instructions are shown in Fig. 3.

3. HARDWARE

UNIROAD Traffic Signal Controller (TSC) is a Z80 microprocessor based system, which is proven to be fail-safe during the past 5 years. The design concepts are published in [6]. The Z80 based Single Board Computer (SBC), the hart of the TSC, supports two RS-232 compatible ports, named Port 0 and Port 1. Signals from those two ports are available for general use as a 20-pin port. In the existing TSC, signals from those ports are used for various purposes such as to receive timer interrupts, to update color lights, to update the display, for sensing the availability of power and for monitoring remote controller as shown in Fig. 4.

Modem Interface Unit (MIU) and General Purpose Input Interface Unit (GPIIU) are two modules added to the existing TSC to meet the requirements of the coordination. The complete diagram of the upgraded controller is shown in Fig. 5. With the help of the MIU, the TSC is remotely accessed through a standard modem using the Public Switched Telephone Network (PSTN) over a standard copper loop or over wireless local loop. The modems are configured to negotiate communication parameters so that the maximum possible data rate can be achieved while maintaining the reliability. But the data rate between the TSC and the modem is limited to 9600 bps to simplify the firmware routines running on the TSC. With the aid of the GPIIU, vehicle detectors and pedestrian push buttons are interfaced to the TSC.

Modem data and General Purpose Input Data (GPID) are transferred sequentially together with Code Display (CD) data over the same serial channel. This is explained in the timing diagram shown in Fig. 6. Data from and to those units are identified according to the state of the "Filter" signal derived from RTS of Port 1.

3.1 Modem Interface Unit (MIU)

MIU controls the remote access port of the TSC. It generates necessary signals for interfacing the TSC to a standard modem under the control of the TSC. Transmission Signal (Tx) and Receive Signal (Rx) with a handshaking mechanism are required for data transferring between modem and TSC. As the data packet size is limited to 36 bytes, and as the buffer size of the modem is high, handshake mechanism for data transferring from TSC to modem is not required. But from modem to TSC a handshake mechanism is require because TSC cannot attend for modem data all the time. Therefore, Request To Send Signal (RTS) is used to control the data flow from the modem. This signal is generated form the RTS of Port 0 of SBC. Additionally, DTR (Data Terminal Ready) signal from the modem is asserted permanently on the MIU so that modem can answer incoming calls automatically.

Tx line is common for both modem and Code Display (CD). Therefore modem data is separated from CD data by using the "Filter" signal. Refer to Fig. 6.

3.1.1. Isolation Unit (IU)

Telephone link is very susceptible to lightning effects. To suppress high voltage MOVs with breakdown voltage of 130 V are used [3]. As an additional protection, the TSC is isolated optically from the PSTN. RS-232 signals are converted into TTL levels and that TTL signals are fed to opto-isolators which provides an isolation of up to 2500 V rms.

3.2. General Purpose Input Interface Unit (GPIIU)

This unit is used to get 24 bit binary (bitmapped) data in. Those data is supposed to come from various devices such as pedestrian push buttons, light failure detectors, vehicle detectors, remote controller, etc. Those signals are latched to an array of shift registers and fed to the SBC through serial port. To get those data in, the same Rx line used by the modem is used. Taking "Filter" signal as the selection signal Rx channels are multiplexed between the modem and GPIIU. High to Low transition of the multiplexing signal is used to load the shift registers with fresh conditions. A free running clock signal of 9600 kHz shits the bits to the Rx line.

4. FIRMWARE

The firmware executed on the SBC determines the operation of the TSC. A given set of signal lights is activated for a given period of time known as a signal interval. At every half a second, the system checks whether time allocated for the current signal interval is over. On the expiry of the allocated time, the light pattern for the next signal interval is activated. This process is repeated for a complete cycle. At the end of the current cycle, next timing plan is determined according to the day and time to minimized the traffic delays. The best timing plan for each 15 minute time slots are stored in the ROM based on a traffic survey, details of this mechanism is reported in [6]. The complete flow diagram is shown in the Fig. 7.

A set of routines was developed as add-on firmware modules to support the new features based on the remote access to the TSC. These routines include a set of data transmission, data receiving, multiplexing, error checking, instruction decode and instruction execution routines as shown in Fig. 8.

4.1. Data Reception Subroutines

Before any data communication transaction to be started, the data path towards the modem must be set up. The communication path is created by asserting the RTS signal of Port 1, which is interpreted as "Filter" signal by the MIU. Then TSC waits for data from the modem. By the end this period one of the following activities may have occurred.

1. 35-byte data packet is received without any error:
   The data packet is considered to be a valid data packet if error-checking routines report no errors. In this case TSC initiates a Download data packet and its "Reply Status" field, shown in Fig. 2 (b), is set to VALID_DATA to inform the CC the correct reception of data packet.

2. No byte is received until time out:
   In this case TSC return from the subroutine without initiating a Download packet.

3. Number of bytes received is less than 35:
   In this event TSC rejects the entire packet, and the "Reply Status" of the Download packet is set to RECEIVE_ TIMEOUT State.

4. While receiving, an serial communication error (Framing error or Overrun error) occur:
   In this event TSC rejects the data packet, and the "Reply Status" of the Download packet is set to TRANSMISSION_ERROR State.

If data packet is received correctly, instruction decode and execution routines are executed. During instruction execution, Download data packet, initiated with VALID_DATA instruction, is filled with responds to each and every Upload instruction. When the Download data packet is ready, a separate Data transmission routine is executed to send the data to the Modem.

4.2. Instruction Decoding and Execution

Instructions received in the data packet are compared with pre-assigned Op-codes for instruction decoding. Method of instruction execution and the number of data bytes involved depend on the instruction itself. Instruction format is given in Fig. 3. For every instruction executed, a reply instruction (a Download instruction) is generated. It informs status of the execution as follows.

1. Instruction execution is ok:
   Successful operation is informed.

2. Instruction execution is failed or not a defined instruction:
   Unsuccessful operation status is issued.

3. Instruction tries to access to unauthorized resources:
   Illegal operation attempt is informed along with that illegal operation.

If the instruction executed is a status or data request instruction, requested status or data is followed by the reply instruction. In that manner, all the instructions in the Upload data packet are executed one by one. If the number of bytes in the Download data packet is less than 36, zeros are appended as padding bytes.

4.3. Data Transmission Subroutine

This routine is executed after the Download data packet is created by the data reception subroutine. It transmits 36-byte data packet to the modem. At the end of the data transmission the modem is disconnected and Tx and Rx signals are released for other functions.

5. SOFTWARE

A stand-alone software package was developed to control and monitor (C&M) the TSC from a remote station via the public telephone network. This C&M software is written for Windows 95 as a user friendly control panel. The C&M software is organized in following three layers as shown in Fig. 9.

1. Communication Port Driver:
2. Low Level Instruction Generation Layer:
3. Operational Layer:

5.1. Communication Port Driver

The C&M software is interfaced to the remote TSC via the Communication Port driver which communicate to the modem via the standard serial port [1]. Tasks assigned to this layer are:

1. Initializing the port
2. Data transmission to modem
3. Data reception from modem

5.2. Low Level Instruction Generation Layer

This is the core layer of the C&M software package. It monitors all the TSC in the system according to actions initiated by the operational layer and issue relevant low level instructions to the TSC. If any error is present, it tries to correct it. If error correction is not possible, an error log is created and an error icon is indicated on the screen for operator intervention.

5.3. Operational Layer

This layer interacts with the operator and generates schedules for Automation and Low Level Instruction Generation Layer. The functions available in this layer are:

1. Manual Control Panel
2. Station installation and configuration
3. Hardware configuration
4. Authorization editor

The operational layer has provisions to add other modules for future expansions related to fully automated timing calculations by the flow model based on CCTV traffic parameter extraction. With this feature, timing relevant to each CLS can be calculated online and timing of each CLS can be adaptively updated.

5.3.1 Manual Control panel

Manual control panel show in Fig. 10 is a user friendly control panel to monitor and control a given TSC, manually. Authorized operators can initiate the communication link to a TSC, simply by selecting it from the station list. As soon as link is established, it shows the layout of the junction and display current situation of the controller including currently opened and closed approaches. Following functions can be triggered manually:

1. Retrieving green interval lengths of a particular plan
2. Overriding green interval lengths of a particular plan
3. Overriding a scheduled plan with new one
4. Overriding a day type
5. Turning all the lights off
6. Giving all aspect amber blinking
7. Synchronizing real time clock of the TSC with that of the Central Controller

In addition to above functions following real time information are displayed on the same panel.

1. Clock information of the TSC
2. Current signals given to each approach (on the junction map)
3. Remaining time for the above signal interval
4. Green interval lengths of the current plan
5. Plan being executed currently
6. Current day type
7. Whether any override is in progress

5.3.2. Station Installation

Station Installation panel, shown in Fig. 11, provides an easy access to enter data related to a TSC used by other subroutines of the C&M software:

1. Junction Name where it is installed
2. Road Names of individual approaches
3. Names of nearby neighboring junctions
4. Road layout diagram of the installations

5.3.3. Hardware Installation

User can select the communication port on which the modem is connected. This feature is provided for selecting one of the communications ports available on the CC.

5.3.4. Authorization Editor

This editor is used to add or remove users or to change their passwords. There are two editor windows available under this category.

1. To edit logging:
   This can only be accessed by supervisor to add or remove users. He can create profiles and assign them initial passwords.

2. To change password:
   This resource is available for individual users to change their passwords.

These profiles stored in a file in an encrypted format. Login information must be provided for accessing secured areas.

6. CONCLUSION

This system provides an easy and cost effective mechanism to operate color light systems in a coordinated manner to reduce bad effects caused by signalization of nearby junctions. This work enables the CLS to operate as an adaptive system, which can be used to configure each CLS to cope up with any emergency situation, easily from a central location. Each and every TSC is monitored frequently for proper operation. If light failure is occurred it is indicated on the central controller, which can be informed to maintenance crew immediately. The system has been tested for more than a year and it will be installed along the Olcott Mawatha, Colombo shortly.

REFERENCES

[1] Campbell J, C Programmer's Guide to Serial Communications.

[2] Fred H, Data communications, computer networks and OSI, 2d edition, Workingham: Addison-Wesley,1988

[3] Golde RH, Lightning Protection., Edward Arnold (Publishers) Ltd., 1973

[4] Haver DA and Tarnoff PJ, Future Directions for Traffic Management Systems, IEEE Transactions on Vehicular Technology, VOL. 40, NO. 1, Feb. 1991

[5] Jayasinghe JAKS, Multiprocessor architecture for adaptive control of traffic light systems, 5th Anniversary Symposium of the Engineering Research Unit, University of Moratuwa, 1999.

[6] Jayasinghe JAKS, Time Indexed Traffic Light System, Transactions of the IEE Sri Lanka Centre, Vol. 2, Dec. 1997

[7] Robertson DI and Bretheroton RD, Optimizing Networks of Traffic Signals in Real Time – The SCOOOT Method, IEEE Transactions on Vehicular Technology, VOL. 40, NO. 1, Feb. 1991

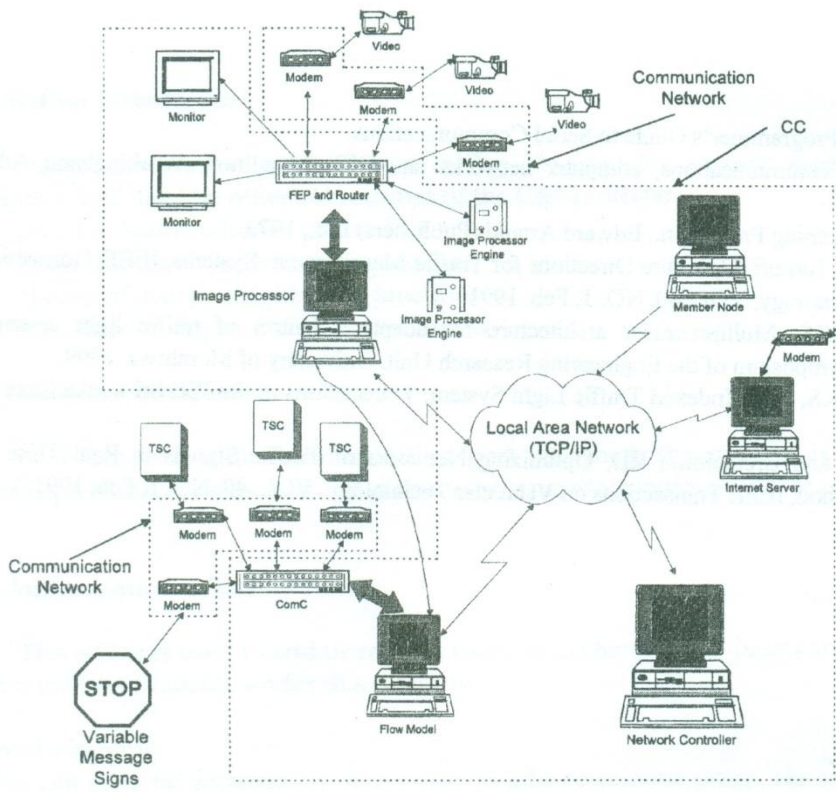

Fig.1. An integrated traffic monitoring and controlling environment.

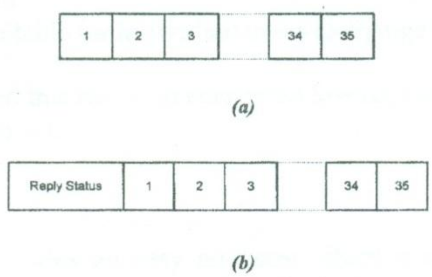

Fig. 2. Data Packet Structure *(a)* Upload Packet *(b)* Download Packet

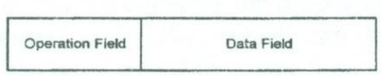

Fig. 3. Instruction Format

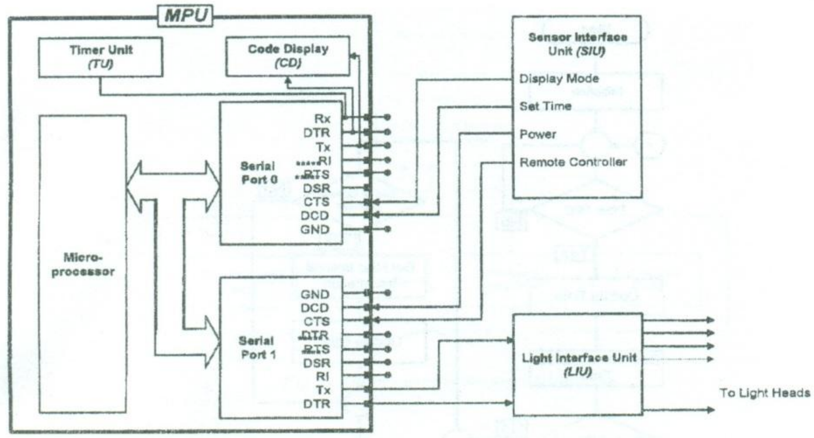

Fig. 4. Existing Traffic Signal Controller

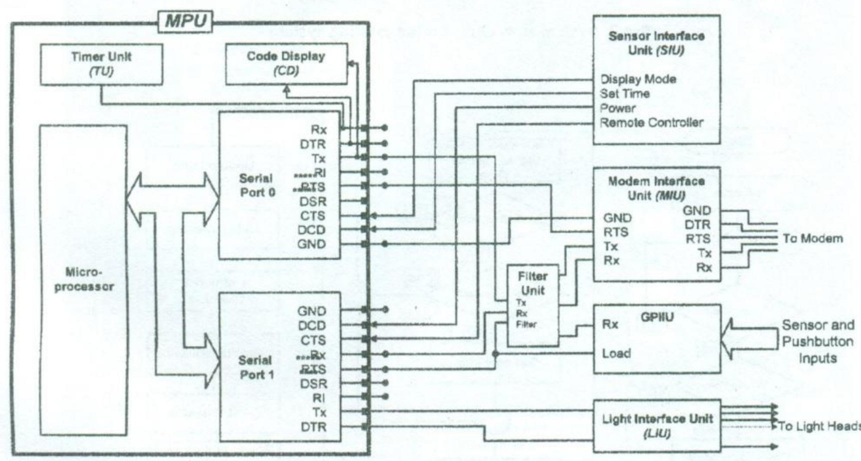

Fig. 5 Complete system developed for the ITS

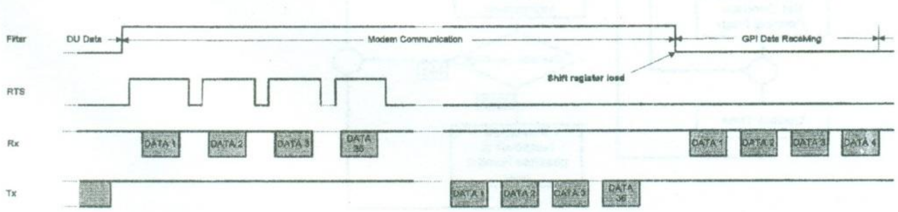

Fig. 6. Timing Diagram for communication and GPI interface

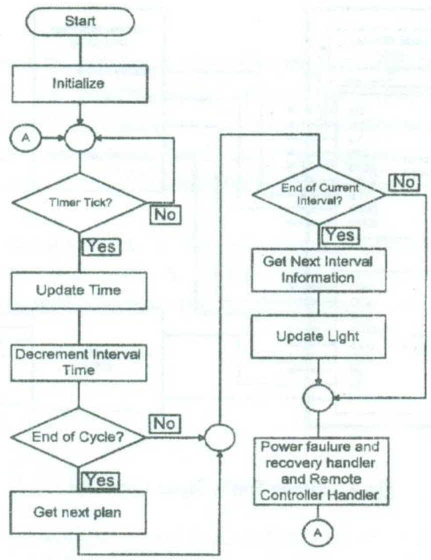

Fig.7. System flow chart for the existing system

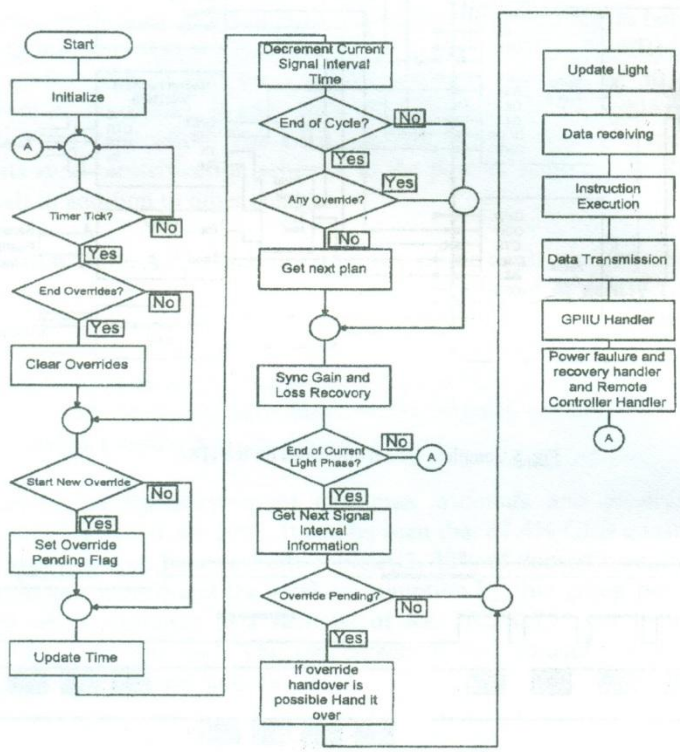

Fig. 8. Compleate System Flow Diagram

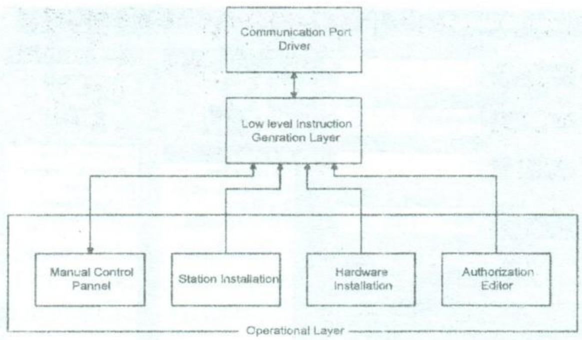

Fig. 9. Three Layer Software Architecture.

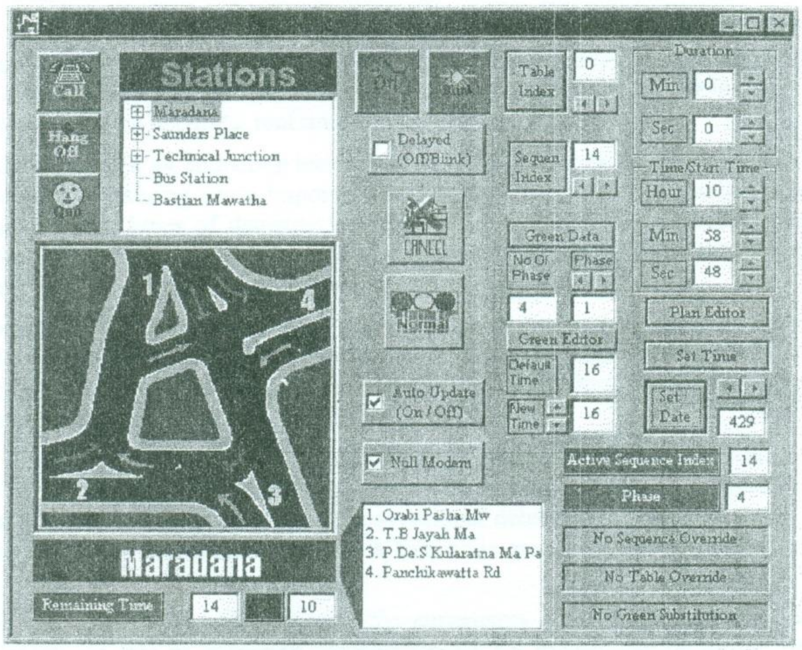

Fig. 10. Manual Control Pannnel – A screen shot taken from the C&M software

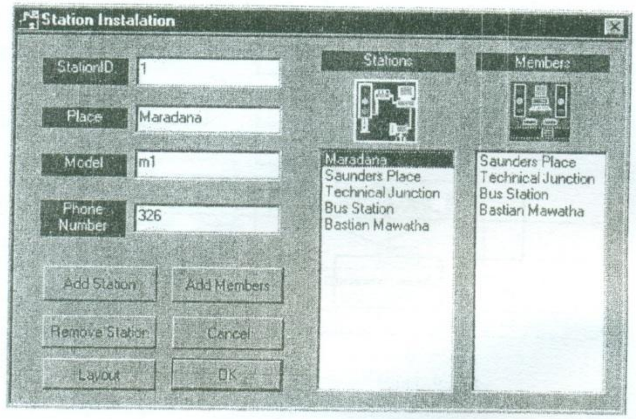

Fig. 11. Station Installation Dialog Box