TWO WAY CABLE TV COMMUNICATIONS FOR CENTRALIZED TRAFFIC CONTROL SYSTEMS

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ABSTRACT

Two-way cable TV networks can provide the communications requirements for centralized traffic control systems, and offer both performance and cost advantages. Wide-area cable plant coverage makes practical the extension of centralized control beyond central business districts. Existing types of traffic controller equipment can be utilized in central control systems by means of adapter interface assemblies built into Remote Communications units connected to the cable system. A combination of Time Division Multiplex and Frequency Division Multiplex techniques are used for efficient utilization of available bandwidth.

Centralized computer-based traffic control systems have good potential for improving the efficiency and traffic-handling capability of existing streets and freeways. Experience gained from existing prototype systems has shown that reductions of 20% to 30% are possible for average travel time and number of required stops(1)

While rapid advances in minicomputer and microprocessor technology have increased the performance and lowered the price of central and remote processing equipment, high interconnection cost has been a major obstacle to the widespread application of centralized traffic control systems. To date, such systems have typically been confined to central business districts, where high traffic densities and limited geographic area have helped to justify the high interconnection costs.

In most present systems, communications between the traffic control center and remote terminals has been provided by dedicated telephone circuits. Such circuits may be leased or private lines. Either way, costs tend to become prohibitive with expansion of the control area and the number of remote terminals. With leased lines, rising tariff rates result in open-ended and increasing operating costs. If a city installs its own lines, installation and maintenance costs are high for wide-area systems. Many such circuits are required. Unconditioned voice-grade circuits are limited to about 2400 bit/second data rates for reliable communications. This sets a practical limit of about eight remote terminals per wire-pair, requiring at least 125 wire-pairs for a system of 1000 controlled intersections.

Two-way cable TV systems provide an attractive alternative for traffic control communications. They offer several significant advantages:

1. Performance

   Individual data carrier channels can transfer data in either direction at rates of 28000 to 56000 bits/second. Seven to fourteen such data channels can be provided within the 6 MHz bandwidth of one standard TV channel. Space is also available for additional narrow-band channels,

(1) Traffic Control Systens Handbook
Federal Highway Administration
Washington, D.C. 1976

useful for system support functions such as point-to-point voice communications and full-duplex RS-232 data links. With cable communications, more remote terminals can be accommodated, and each terminal can be polled more often.

2. Availability and Coverage

By necessity, the cable plant of a TV system must follow all city streets, or at least along nearby alleyways. This universal coverage makes possible the inclusion of virtually all city street intersections within a control area, regardless of its size.

3. Cost

The cost of a wide-spectrum two-way cable TV system can be shared and amortized by all services using it. Considering the large number of TV channels available on modern cable systems, it is possible that the spectrum space required by even the largest traffic control systems may otherwise go unused.

4. Special Capabilities

Wide bandwidth traffic control functions, such as real-time video surveillance of potential trouble spots, are easily provided by cable communications. This feature is impossible with narrow-band telephone circuits.

Centralized Traffic Control Systems

Centralized traffic control systems are designed to maximize traffic flow, reduce delays, and provide aid or information for motorists. Two major categories of such systems have evolved:

1. Urban Street Surveillance and Control.
2. Freeway Surveillance and Control.

In either of these two major traffic control applications, traffic data is collected by the Central Processing Unit (CPU) from many roadway vehicle detectors throughout the system. In an urban street control system, the CPU uses this traffic data to determine optimum timing plans for each individual intersection controller in the system. For freeway control, data collected from detectors in each traffic lane and entrance ramp are used by the CPU to determine metering rates for each individual ramp controller. Timing plans or metering rates are updated as required, and implemented at each local controller by addressed control commands transmitted from the CPU. These control commands are updated frequently, usually at intervals of one second or less. Each remote terminal receives an updated control command at the same time that it is polled for vehicle detector data.

The most common type of vehicle detector consists of a multi-turn loop of wire embedded in the road surface. The loop is connected to an interface unit that generates one logic level when a vehicle is over the loop, and the opposite logic level when a vehicle is absent. Several detectors may be installed in the vicinity of an intersection. They may be placed on one or more intersection approaches, and in one or more lanes of each approach. On a freeway system, detectors may be placed at approximately one-half mile intervals in each lane, and also at selected locations on each entrance ramp. A single remote terminal has multiple input ports to receive the output lines from several detectors, which can be at locations up to one mile away.

In TOCOM traffic control technology, the remote terminal is called the Remote Communications Unit (RCU). Included in the RCU is an RF transceiver for communication with the traffic control center, processing and control logic, an adaptor assembly for local controller interface, and detector input signal-processing/logic circuits. An RCU may be designed to take as many as 16 detector inputs and provide up to 16 control outputs.

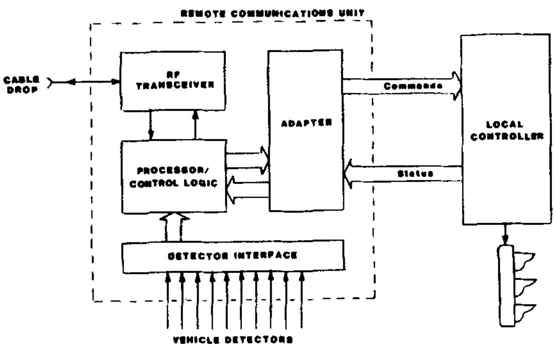

Figure 1. Remote Communications Unit

From each detector input signal, the RCU processes two basic traffic parameters - volume and occupancy, which are updated every second. Volume is a measure of traffic flow, in vehicles per minute. Occupancy is a measure of traffic density, and indicates the percentage of time that a vehicle is over a detector loop. These two parameters are formatted (two bits for volume, five bits for occupancy) and stored in registers to await transmission to the CPU, in response to an interrogation request from the traffic control center.

The adaptor assembly of an RCU is designed to be compatible with the type of local controller to be used. Relay contacts are provided for electromechanical types of controllers. Appropriate logic levels are provided for solid-state controllers. In addition to providing vaious control lines, the adaptor unit also receives status inputs from the local controller. As many as 16 status bits are stored in a status register, to await transmission to the control center in response to an appropriate interrogation request.

Urban Street Traffic Control Systems

In an urban street traffic control system, the central CPU analyzes the raw volume and occupancy data received from all points in the system. Using this data, timing plans are selected for each individual intersection. In most present systems, as many as 25 standardized timing plans are stored in memory and selected according to pre-determined criteria for volume/occupancy conditions. With more sophisticated software being developed for future systems, the volume/occupancy data will be used to directly compute unique timing plans on a real-time basis for additional flexibility.

A timing plan is defined by three basic intersection controller parameters:

1. Cycle Time
2. Split
3. Offset

Cycle time is the time required for a controller to go through a complete sequence of all possible phases. (Phases are the individual states during which no signal changes are made, such as major street green, minor street green, left turn, etc.).

Split is the proportion of green time alloted to competing phases.

Offset is a time difference between a zero reference time and a defined point on the time cycle of individual traffic signals in a co-ordinated sub-system. Such sub-systems may consist of a progressive series of traffic signals along a major thoroughfare. In non-centralized systems, the individual signals in such a sub-system are controlled by slave controllers, hard-wired to a master controller. The master controller determines the zero reference time and offset for each individual traffic signal. Offset does not apply to controllers used for isolated intersections.

Two basic types of intersection controllers are commonly used in non-centralized traffic control systems:

1. Pre-timed Controllers
2. Traffic-actuated Controllers.

Pre-timed controllers are often used in co-ordinated subsystems along major arterial streets. Their timing plans are established by settings on an electro-mechanical dial unit or an electronic timing module. Once set, the timing plan is inflexible and unresponsive to traffic conditions. Some pre-timed controllers have more than one timing unit. With a three-dial controller, three preset timing plans can be scheduled for different times of the day, corresponding to AM-peak, PM-peak, and off-peak conditions.

Traffic-actuated controllers are often used at isolated intersections. They do not have preset timing plans. The green time assigned to a phase is dependent on "calls" from detectors actuated by traffic. One phase may receive a green light indefinitely if no calls are received from an opposing phase. Such controllers can be co-ordinated with controllers at nearby intersections by the addition of a special co-ordinating dial unit. A new version of traffic-actuated controllers is the micro-processor controller, which is useful for complex intersections. It has memory storage capability for holding actuator data, and can compute appropriate timing plans on a real-time basis.

Most modern pre-timed and traffic-actuated controllers are equipped with means to suspend normal operations and operate under direct control of external signals from a control adaptor. One of the control lines from the TOCOM RCU adaptor assembly is a master control called "Hold On-Line". When active, the timing plan of the interconnected controller will be established by the other control lines. One of those other control lines is an "Advance" control. When pulsed, the advance control causes the controller to advance to the next phase. The controller remains in that phase until it receives another advance pulse. The frequency and timing of the advance pulses therefore establishes the timing plan of the controller when "Hold On-Line" is active. The other control lines serve various other purposes, such as to place the controller in a red/yellow flashing mode, turn on school zone signs, and to pre-empt the controller for special accommodation of emergency vehicles, railroad crossings, etc.

When the "Hold On-Line" control from the RCU becomes inactive, the interconnected controller reverts back to its normal "off-line" mode of operation. This fail-safe feature of the system provides a standby mode of operation, which is actually a normal non-centralized control mode. As long as the "Hold On-Line" control is active, all intersection controllers operate in the same mode, under the direct control of the CPU in the traffic control center. When the "Hold On-Line" control becomes inactive, all controllers return to the specific mode of operation for which they were designed - pre-timed, traffic-actuated, etc.

Most controllers are designed with auxiliary contacts, providing status signals for confirmation of proper controller operation. Up to 16 status input ports are provided on TOCOM RCU's. Signals appearing on these ports are transmitted as status flags back to the control center.

<u>Freeway Traffic Control Systems</u>

In freeway control systems, the traffic detector and communications equipment is similar to that used for urban street systems. The traffic detectors are typically spaced at regular intervals in each traffic lane, and also in the entrance ramps. Reduction of freeway congestion is the basic goal of such systems, which include one or more of the following functions:

1. Entrance Ramp Control
2. Frontage Road or Corridor Control
3. Variable Sign Control
4. TV Surveillance.

Entrance ramp control is the most common function of present freeway systems. The CPU at the control center uses volume and occupancy data to determine metering rates of entrance ramp traffic signals. Ramp controllers are interfaced with RCU's similar to those used for urban street systems. The ramp metering rates are determined by comparing current traffic flow and density to the capacity of the freeway. When a freeway is near its capacity, metering rates are kept low, forcing traffic to alternate routes.

With frontage road control, timing is adjusted on intersection signals along frontage or service roads alongside the freeway. Under normal freeway conditions, the timing of such signals may favor cross-street traffic. However, when freeway traffic becomes congested, timing may be adjusted to a more progressive pattern, to allow frontage roads to carry part of the freeway traffic more efficiently. Signal timing on so-called "corridor" streets paralleling a freeway may also be adjusted in the same way.

Motorist advisory information may be provided by variable signs placed along the freeway, carrying messages related to traffic conditions ahead, accidents, variable speed limits, etc. Each sign would be interfaced to a remote terminal that receives appropriate data from the CPU, addressed to the specific location.

TV camera surveillance may be used at selected high-density, trouble-prone locations. Remote cameras can be panned right and left, tilted up and down, zoomed, focused, and adjusted in various other ways by console controls in the traffic control center. Real-time high resolution video signals require a full 6 MHz TV channel. If several camera locations are required, the 5-30 MHz return bandwidth available on a conventional CATV Cable System may be inadequate. An alternative solution would be time-sharing of one or more channels by several cameras, whose transmissions could be controlled by selective commands on a separate control channel.

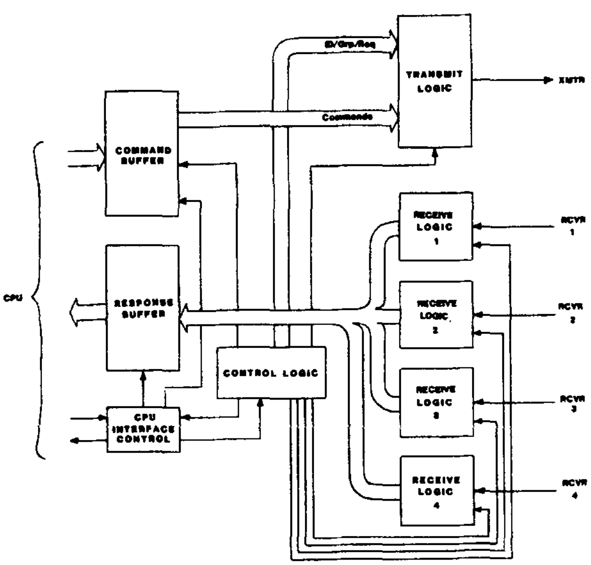

Figure 2. Communications Control Unit

System Organization & Communication Format

In a recent TOCOM system design, 400 Remote Communication Units are interrogated and commanded every second. Update commands are transmitted from the control center to each RCU within the same message structure used to interrogate for detector and controller status data. In the Control Center, a Communications Control Unit (CCU) handles data transfers to/from the CPU. It contains the buffer memories and control logic required to scan 400 RCU's. The memories are double-buffered, so that command and response data can be block-transferred to/from the CPU by means of one set of buffers while data from the other set is being distributed and received to/from all the RCU's. The CCU is illustrated by Figure 2.

A combination of Frequency Domain Multiplex (FDM) and Time Domain Multiplex (TDM) is used to scan all RCU's. In the above-mentioned system, the 400 RCU's were divided into four groups of 100 RCU's each. Unique identification (ID) codes are assigned to each RCU in a group. All RCU's receive transmissions from the control center on one common data channel. They respond on separate data channel frequencies, each common only to the RCU's within one group. Transmissions from the control center include the ID code and a group code, along with a command code. Following each control center transmisssion, four RCU's sharing a common ID code respond simultaneously on four separate group channels. The ID and group codes in each transmission identify a unique RCU, whose logic circuits will latch the transmitted command code into a command register. The 16-bit RCU response following the control center interrogation is sufficient to transfer one 16-bit controller status word, or to transfer volume/occupancy data from two vehicle detectors. To transfer a complete set of RCU data (with ten vehicle detectors connected to one RCU), six separate interrogation sequences are required for each ID/group code combination. To distinguish between these six separate parts of the RCU response data, a request code is added to the interrogation transmission from the control center, along with the ID and group codes. For each ID code, the request code is incremented six times. Then the ID code is incremented to interrogate four more RCU's. Every second, this sequence continues through 100 ID code combinations, with a different set of four RCU's responding (on four separate frequencies) for each ID combination. In this way, command and response data can be transferred to/from 400 RCU's every second, with volume/response data coming from ten vehicle detectors per RCU.

The interrogation sequence is illustrated by Figure 3, which shows the four-byte interrogation transmission format from the control center, followed by two-byte responses from the four RCU's sharing a common ID code; one RCU from each group.

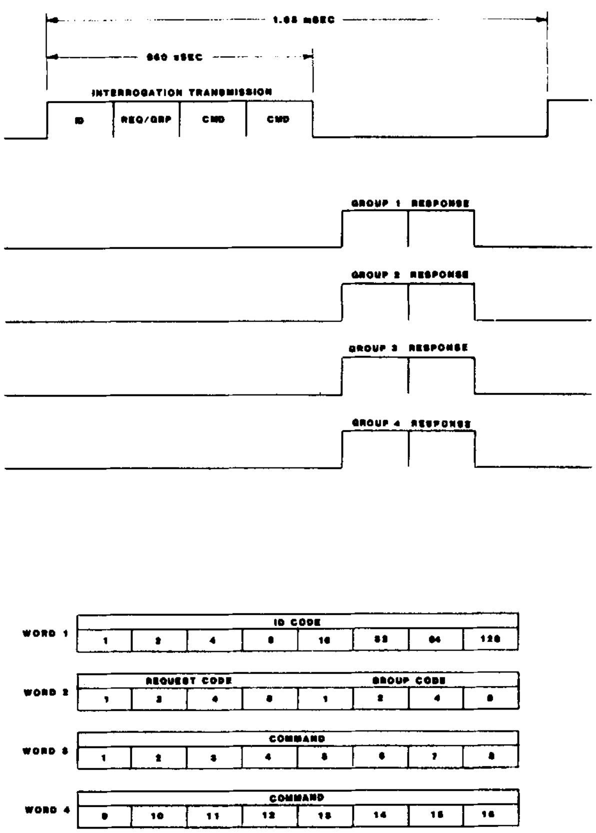

Figure 3. Interrogation Sequence

By expanding the number of data channels and/or modifying the message format, the number of RCU's can be increased. A system size up to at least 1500 RCU's (intersections) can be accommodated within the bandwidth of one standard TV channel in each direction.

Ancillary functions, such as point-to-point voice communications and RS-232 data links, are required in a practical system for maintenance and support activities. Three additional narrow-band channels in each direction are added for these functions. One set of these channels is reserved for voice communications and the other two are for a full-duplex RS-232, 9600 baud data transfer link. All remote units, whether voice or data-modems, transmit on a low-band upstream data channel. By means of a block up-converter at the traffic control center, these narrow-band upstream channels are translated to equivalent down-stream channels, to which receiver sections of the voice of data units are tuned. In this way, any remote voice communications unit or data modem can communicate with any similar unit at any other point in the system, including the traffic control center.