City of Sarnia

Task 10 - Procurement Plan: Traffic Signal Control System Assessment
32588

Transportation Master Plan and Public Transit Master Plan

Prepared for City of Sarnia
by

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1. Introduction

The City of Sarnia retained IBI Group to develop a Transportation Master Plan (TMP). Part of the TMP is to conduct an assessment of the traffic data communications infrastructure. The objective of this technical report is to review the existing traffic signal control system (i.e. central software, and field equipment) and identify equipment upgrades/replacement necessary to support the TMP.

This report is divided into the following sections:

- **Section** 2 – describes the traffic signal control system standards in details;
- **Section** 3 – presents an overview of the inventory of the existing traffic signal control system;
- **Section** 4 – proposes a future advanced transportation management system architecture, and describes the evolution of the City's existing traffic signal control system components; and
- **Section 5** – provides report recommendations.

2. Traffic Signal Control System Standards

This section describes traffic signal control system architectures common in the industry, describes controller standards, and provides a description of the National Transportation Communications for ITS Protocol (NTCIP).

2.1 Traffic Signal Control System Architecture

The two predominate traffic signal control system architectures used in the industry are a three level distributed system (or closed loop system), and a two level distributed system (or an Advanced Traffic Management System). These two systems are described in the following.

2.1.1 Three Level Distributed System – Closed Loop

This sub-section provides historical background of a closed loop traffic signal control system. A closed loop system is used by the City of Sarnia.

- 1980's style system;
- Often described as a three level distributed system, with the three levels being central software, field master and local controller.
- Communication occurs between the central software and the field master, and the field master to the local controller. Communication from the central software to the local controller occurs through the field master.
- The term "closed loop" describes the communication between the master and controller, which happens in both directions. As an example, the field detectors connected to the controller provide data on current traffic conditions. The master uses the data report from the controller in a traffic responsive algorithm to select timing plans that best match on-street conditions.

- Traditionally twisted pair cables are used to connect the field master to the local controller, while a dial-up leased service is used for communication between the central software and the master;
- The system used proprietary communication protocols on low-bandwidth communication system. An operating speed of 19.2 Kbps was the highest achievable with the communication technology. Most operated in the 1,200 to 4,800 bps range;
- The central software is a database that is used to upload and download signal timings and settings in the master; and
- On-street operation was achieved through the use of the master, sending time synch pulses, and timing plan changes to the local controllers. Traffic responsive control was implemented through the master.

2.1.2 Two Level Distributed System – Advanced Traffic Management System

In the early 1990s, the National Transportation Communications for ITS Protocol (NTCIP) was introduced. The NTCIP focused on communications between the central traffic signal control system, referred to as an Advanced Traffic Management System (ATMS) and the controller. The use of the field master was eliminated through the use of NTCIP. Overall, the objective was to use modern communication technologies and migrate towards an Ethernet communication network. This resulted in eliminating the need of a purpose-built communication system for a traffic signal control system.

The ATMS allowed for functionality beyond basic signal control. Users can upload and download signal timings, monitor remotely, collect Measure of Effectiveness (MOE's), and now evolving into "active management" in the urban environment in larger centres. Where similar to the freeway management applications, the traffic engineers can monitor current traffic conditions through a host of surveillance technologies, such as Bluetooth readers and CCTV cameras, and detectors to collect information on current traffic conditions. Then the signal controllers can efficiently respond to events.

2.2 Controller Standards

In the early 1970's two concurrent traffic controller standards efforts were initiated in North America. These were the Model 170 standard, and the National Electrical Manufacturers Association (NEMA) standard. Today, these are the two predominant controller standards used in the traffic signal control system industry. A brief history of these two standards efforts, and, are presented below.

The information presented herein was gathered from the following publications:

- Advanced Transportation Controller (ATC) ATC Standard 5.2b; and
- NEMA Standards Publication TS2-2003 v02.06 "Traffic Controller Assemblies with NTCIP Requirements".

Traditionally the controller market was divided into NEMA and 170/2070/ATC controllers. These two standards differed in many ways from a hardware and software perspective, but are operationally similar. Most vendors have one basic software application that is used in both NEMA and ATC controllers. More importantly controller-cabinet interface standards are used to allow "interchangeability" between controllers and cabinets.

2.2.1 National Electrical Manufacturers Association

The majority of municipalities within Canada use NEMA TS1 traffic signal control system field equipment. However, municipalities are starting to migrate to the NEMA TS2 standard, which simplifies the cabinet assembly and reduces potential failure points. The current equipment in the City of Sarnia is NEMA TS1.

The NEMA standard(s) stemmed from a group of manufacturers who joined NEMA and assembled a core of experienced traffic and electronic engineers to define the first NEMA traffic signal controller. The controller development consisted of an interchangeable electronic device with standard connectors. The NEMA standard further defined traffic terminology and minimum traffic signal control software functionality. Various user agencies including State, City, and County Government Officials participated in this initial definition of the standard.

The initial standard, published in 1976, included the standardization of connectors and connections for three “MS” style connectors. The inputs and outputs were defined and standardized with respect to electrical levels, as well as function. The development process ultimately yielded a document labelled the “TS-1” Traffic Controller Assemblies - Standard published in 1983. The NEMA standard also defined peripheral devices used in the controller industry and eventually defined the cabinet. The NEMA process requires that every six years the standard is updated and re-ratified.

The NEMA TS1 standard did not cover communications between devices, nor did the standard provide for interchangeability of software functions. Limitations inherent in NEMA TS1 were seen as follows:

Reliance on point-to-point wire connection for all functions with termination points for all wires, many of which are not used, has the following limitations:

- Numerous connections increase failure potential;
- Not cost effective;
- Hardware limited expandability;
- Out-of-date technology, particularly relating to communications; and
- Lack of uniformity in the implementation of the following functions and the resulting loss in equipment interchangeability:
    - Coordination;
    - Time base control;
    - Pre-emption;
    - Communications;
    - Diagnostics; and
    - User interface.

During subsequent years, the demand for communications to provide data transfers between local controllers and central control, or on-street master systems (closed loop), increased rapidly. The original TS-1 standard had not defined communication and subsequently a non-standard fourth connector evolved that did not allow interchangeability. The TS-1 1989 revision defined/standardized actuated intersection control, provided standards for all cabinet components, added test procedures, and improved the interchangeability between manufacturers equipment, however, many non-standard functions remained.

The NEMA TS1 standard was subsequently revised, and re-affirmed in 1989:

- Defined effective actuated intersection control;
- As a complete package, defined all equipment within the cabinet and test procedures;
- Provided equipment interchangeability between manufacturers; and
- As a minimum functional standard, facilitated design innovations.

Over the years, further definitions were recommended to define a safer cabinet-to-controller interface. This new recommendation included a full Synchronous Data Link Communication (SDLC) protocol, to allow the traffic controller and the conflict monitor to communicate between each device and check the intended output with what was actually being displayed by the cabinet.

This effort generated the most recent "TS-2" standard in 1992, later updated in 1998 and 2003. The standard outlines an expandable and interchangeable traffic controller, cabinets, and peripherals. The TS2 standard replaced individual Parallel I/O lines with time slots in a high-speed serial data stream, reducing the amount of cabinet wiring and allowing the easier addition of new features.

The Standards Publication NEMA TS2-2003 is predicated upon an industry perceived need to overcome limitations of the NEMA Standards Publication TS1, Traffic Control Systems, which in 1976 reflected the first industry documentation of technically adequate and safe traffic control equipment.

The NEMA TS2 Standard was established to overcome the limitations in the NEMA TS1 Standards Publication, including:

- Equipment requirements based on valid engineering concepts;
- Interchangeability, performance oriented, without precluding downward compatibility with TS1 equipment;
- Emphasis on use of enhanced diagnostic techniques;
- Minimize potential for malfunctions;
- Provide for future expandability; and
- Enhanced user interface.

In order to respond to these deficiencies, a new performance-oriented standard (TS2), was developed. The advantages of a new performance-oriented standard were identified as:

- Communication between major equipment within the cabinet over a data channel with virtually unlimited capacity. Potential for future expandability is thereby maximized;
- Use of a high-speed data channel between the controller unit, MMU, detectors, and rear panel reduces the number of connections and facilitates diagnostic testing, thereby reducing the potential for malfunction;
- Cost-effectiveness of communications protocols; and
- Enhanced user interface.

During the development of the new NEMA Standards Publication TS2, two approaches evolved:

- Type 1, which uses a high-speed data channel between all major equipment to maximize the functionality and expandability; and

- Type 2, which retains the MSA, MSB, and MSC connectors for data exchange with the rear panel, providing a degree of downward compatibility with TS1 cabinet assemblies.

The standard however, did not accommodate interchangeable software among the various manufacturers. Features found in one software package were not available in another's package. Also, the front panel displays and the information displayed are different for the various manufacturers, and are not standardised.

2.2.2 Advanced Traffic Controller

With the introduction of ATC controllers, most vendors have been following a similar development path (ATC Standard 5.2b is the latest standard available, published in June 2006). The goal of the ATC standard is to provide an open architecture design for transportation controller applications. The ATC can be shelf or rack mounted, and complies with various industry standards, such as:

- The ITS Cabinet standard and the Model 332 cabinet specifications; and
- NEMA TS1 or TS2 standard specifications.

Note that depending on the vendor, the ATC can provide backward interface compatibility with existing NEMA TS1, TS2, Caltrans Model 170, NYDOT Model 179 and ATC 2070 controllers and Model 332 and ITS cabinets.

The ATC is a current generation "Open Systems" controller system standard. Caltrans and the City of Los Angeles originally developed the standard to address some of the limitations associated with the Model 170 and 2070 controllers. Their designers tried to mitigate some of the potential parts obsolescence issues that plague the Model 170. Instead of relying on the efficiency of assembly language programming, the ATC controller unit includes the necessary resources to execute programs written in high-level programming languages such as ANSI C or C++. Such programming languages are more easily written and debugged, and are capable of being ported to other hardware platforms as necessary. The ATC 2070 also specifies the use of an Operating System -O/S (OS-9) to separate the hardware from the application software. By specifying an O/S, the explicit mapping of user memory and field I/O, as was done with the Model 170, is no longer necessary. The O/S and associated standardized support functions take care of many of the basic execution management and scheduling tasks required by application software programs. The O/S further extends the hardware/software independence through I/O and memory resource sharing capabilities. These capabilities operate simultaneously on a single controller unit in a multi-tasking mode. This was not the case with a Model 170.

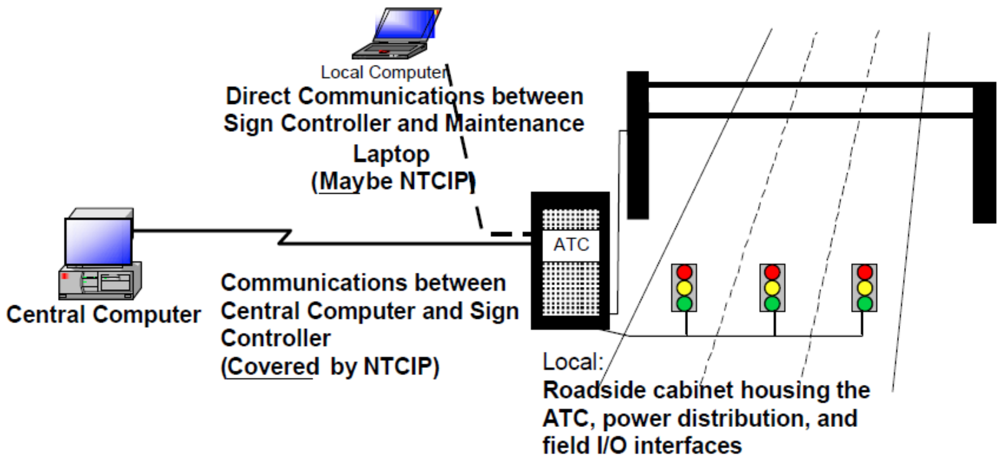
The ATC 2070 standard also provides for greater subcomponent interchangeability and modularity than the Model 170. ATC 2070 component modules are defined through specification such that they are interchangeable among different manufacturers. With the Model 170, only the modem/communication and memory modules are interchangeable among controllers produced by different manufacturers.

However, the ATC 2070 requires that a specific CPU chip and a specific commercial O/S be used. Unfortunately, the embedded hardware and O/S marketplace is not as competitive as the PC marketplace. As a result, longevity concerns are surfacing for the ATC 2070 related to the particular O/S and CPU selections. Many users are concerned that additional retrofit and software porting costs would be required should either this O/S, and/or the CPU, become unavailable.

The O/S for the ATC must be Linux and must include standard Portable Operating System Interface (POSIX) libraries for application support, including real-time extensions of POSIX 1003.1b. A specific engine board design and CPU module pin-outs are specified, however many pins are designated as reserve to allow for future enhancements. Basically this means that the ATC could be upgraded with newer processors. In terms of communications capability, the new ATC uses a modular approach where units for specific types of communication (e.g. radio frequency, infrared, fibre, dialup mode, Ethernet, etc) are supported by adding in units on an application specific basis.

Exhibit 1 illustrates an overview of the typical ATC system environment. Note that the same system environment can be used with a new NEMA controller.

Exhibit 1: Typical ATC System Environment



2.3 National Transportation for ITS Communication Protocol

The primary objective of the National Transportation Communications for ITS Protocol (NTCIP) is to provide an open communications standard that ensures the interoperability and interchangeability of ITS devices.

Interoperable means that different devices, from one or more vendors, may use the same communication channel without interfering with their respective operation. For example, system software from developer A can communicate on the same channel with traffic signal controller from vendor B and Dynamic Message Sign (DMS) from vendor C. The objective is to implement a single central software that uses one communication system (that may be a mix of wireline and wireless technologies), rather than a communication system purpose-built for traffic signal control and DMS control. Cost efficiencies are realized through the single communication system and central software. Furthermore, operating efficiencies are achieved by using one central software for both devices. For example, when the signal system identifies a traffic condition through traffic responsive control, the central software changes the message on the DMS to relay the changed traffic condition to the motorist.

Interchangeable means that a particular device, which may be sourced from multiple vendors, can be controlled/monitored by the same central software system (same driver). If a particular device requires replacement, the system owner/operator may purchase the replacement device from multiple vendors, with the assurance that their central software will NOT require modification. While the objective of NTCIP's standard for interchangeability is to not require software modification, the reality is that software modification is a requirement for many of the traffic signal control system functions, discussed further in this section. Device interchangeability provides many benefits, including the reduction of system integration and maintenance costs, and the long-term reduction of software development and device costs.

The use of NTCIP in ITS initiatives can also translate into the following benefits to the operating agency:

- Avoid early obsolescence;
- Provide a choice of vendors for system expansions and device replacements;
- Reduce the complexity of interagency system control/monitoring coordination;
- Allow the use of one, all-purpose communications network;
- Reduce system integration time/cost;
- Reduce system maintenance time/cost;
- Long-term reduction of software development costs; and
- Long-term reduction of system expansion time/costs.

The following section provides a brief introduction to NTCIP. Information is based on the NTCIP Guide, NTCIP 9001 V02.06, which is an update to the previous document TS3.1 – Overview of NTCIP.

NTCIP is a protocol designed for the transportation industry (based on the US National ITS Architecture) that defines and specifies a communications interface between disparate hardware and software products. It is a family of communications standards that is used for the transmission of raw data and control messages within Intelligent Transportation Systems.

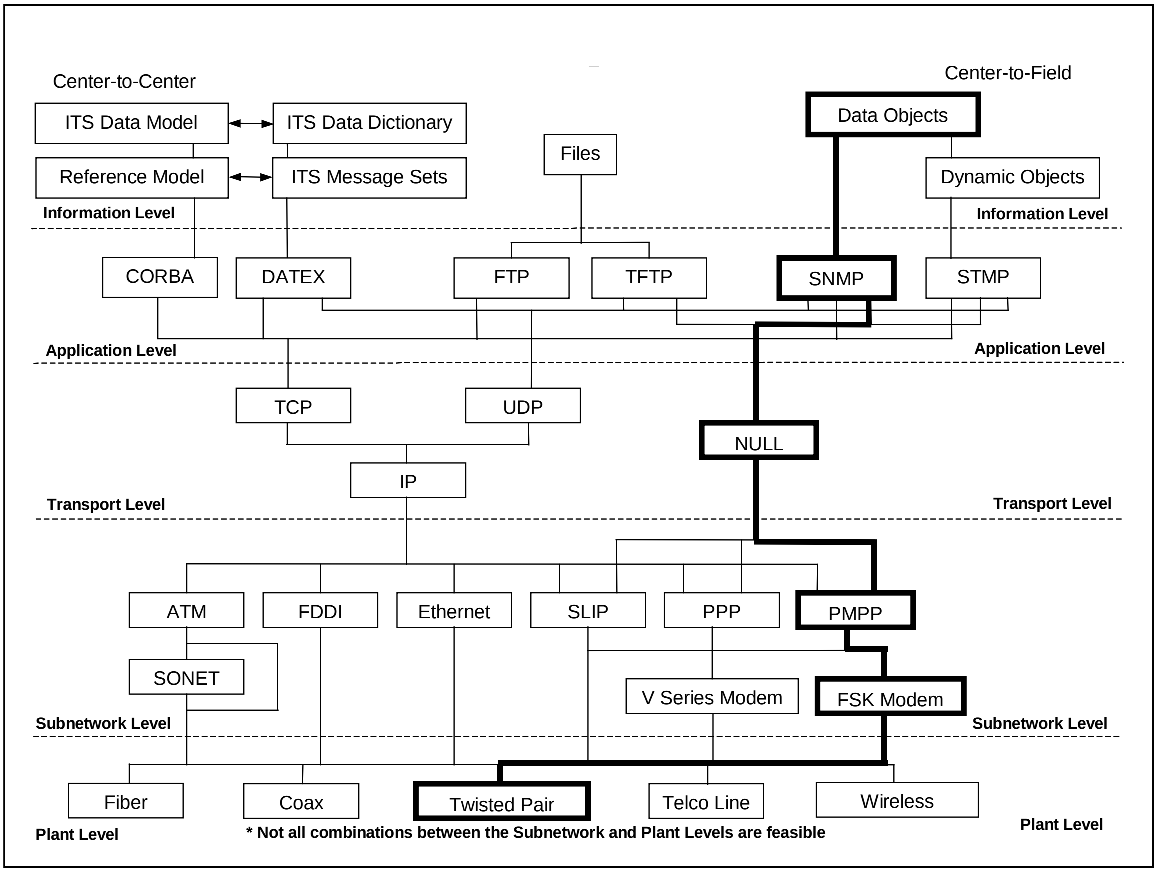
NTCIP encapsulates and specifies two different types of communications interfaces for ITS. The first type of interface is specified for communications between a central management system and multiple field devices for remote monitoring and control. This communications interface is referred to as ‘centre-to-field’. The second type of communications interface links central management systems, and is referred to as ‘centre-to-centre’.

The NTCIP framework consists of a suite of protocols covering the protocol spectrum from simple point-to-point command/response protocols to sophisticated object-oriented techniques. The NTCIP framework is based on a layered approach to communications standards development, similar to the International Standards Organization (ISO) Model (as is the Internet), but with five levels:

- Information Level – Provides standards for the data elements, objects, and messages;
- Application Level – Provides standards for the data-packet structure and session management;
- Transport Level – Provides standards for data-packet subdivision, packet reassembly, and routing;
- Subnetwork Level – Provides standards for the physical interface and the data packet transmission method; and
- Plant Level – Consists of the physical transmission media used for communications.

Exhibit 2 illustrates the NTCIP framework. The boxes represent the different standards that can be chosen at each level, and which ones are compatible (lines connecting boxes). The series of standards used in the message transmission is called a “stack” of standards, or a “protocol stack”.

Exhibit 2: NCTIP Framework with Example Centre-to-Field Stack



The stack is a subset of the overall NTCIP framework – a particular route through the levels. The path shown in bold in the above exhibit illustrates one variation of a centre-to-field protocol stack that could be used by a traffic signal management system. The lower levels are based on existing standards used in the telecommunications industry and were not developed by NTCIP. The first two levels (Information and Application) contain standards unique to ITS.

The Standard Publication NEMA TS2 1998, Traffic Controller Assemblies with NTCIP Requirements, identifies NTCIP standards required for compliance. These standards are contained within the Information and Application levels of the protocol stack. The NEMA Standard Publication identifies following standards for NTCIP compliance:

- TS3.2 – Simple Transportation Management Framework;
- TS3.3 – Class B Profiles;
- TS3.4 – Global Objects; and
- TS3.5 – Actuated Signal Controllers Objects.

The NEMA TS2 Standard describes two levels of NTCIP conformance (compliance).

2.3.1 Level 1

The Level 1 conformance uses the Simple Network Management Protocol (SNMP) at the Application Level and supports only the mandatory NTCIP objects from TS3.4 and TS3.5. The mandatory objects of these two NTCIP standards do not address the advanced functions relative to coordination, time base, pre-emption, system control, overlaps, or the TS2 port 1.

Level 1 conformance alone is not suitable for most traffic signal system applications.

2.3.2 Level 2

Level 2 conformance uses both SNMP and Simple Transportation Management Protocol (STMP) at the Application Level and includes most Information Level objects defined in TS3.5. The TS3.5 objects required for Level 2 conformance create a data dictionary that is used to facilitate most of the advanced controller functionality defined in the NEMA TS2 1998 standard. The TS3.5 data dictionary includes objects that are grouped under the following headings (a complete list of objects is available in The NTCIP Guide pages 47 to 52):

- Phase – Includes objects for pre-timed, actuated, volume-density operation, etc.;
- Detector – Includes objects for vehicle detection (stop bar, extension, queue, volume, occupancy, etc.), pedestrian detection, detector alarms, etc.;
- Unit – Includes objects for controller configuration and monitoring, such as control mode (e.g. system control, timebase, interconnect, etc), flash status (intersection not in flash), special function status, etc.;
- Coordination – Includes objects for coordinated operation such as offset, split values, cycle times, etc.;
- Time Base – Includes objects for time base operation such as synch parameter, pattern selection, etc.;
- Pre-empt – Includes objects for pre-emption such as pre-emption type, ranking, pre-emption sequence, etc.;
- Ring – Includes objects for ring design and operation such as number of rings, stop time, force off, pedestrian recycle, etc.;
- Channel – Includes objects for channel configuration and monitoring such as the maximum number of channels the controller supports, the channel control source (phase or overlap), channel flash parameters, channel control (vehicle phase, pedestrian phase), etc.;
- Overlap – Includes objects such as overlap type, overlap phase parameters, overlap status, etc.; and
- TS2 Port 1 – Includes objects for configuring Port 1, such as address and monitoring port 1 (port status), etc.

The controller functionality described in the Standard Publication NEMA TS2 surpasses most of the current operational requirements of most traffic agencies. However, some advanced features such as transit priority (beyond emergency vehicle pre-emption) are not a requirement of the NEMA TS2 Standard Publication. Similarly, adaptive control is not a NTCIP specified requirement, since this function currently resides outside the local controller (e.g. either centrally driven or an additional processor added to controller). This functionality (transit priority, adaptive control) could potentially be incorporated into the NTCIP protocol but would be vendor specific (i.e. proprietary).

3. Inventory of Existing Equipment

For this assessment, the City staff provided the project team with an inventory of existing traffic signal controllers (e.g. make, model, communication module). The City of Sarnia also maintains signalized intersections that are owned by the County of Lambton. Details of the existing equipment are shown below.

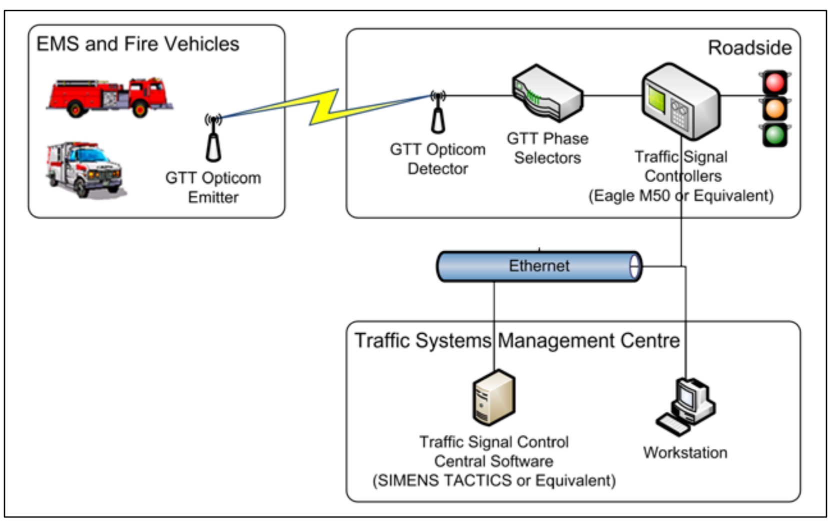
- Central Traffic Signal Control System Software – Siemens MarcNx;
- Communications infrastructure – MDS Spread Spectrum Radio and Hard Wire (i.e. single pulse copper wire);
- Controller make/model, vintage and standards – Siemens/Eagle EPAC 3108-M03, 3208-M10, 3208-M10S, 3208-M34, 3208-M40 and 3208-M50;
- Cabinet assembly vintage and standard – Tacel Cabinets, 1980 to present; and
- Emergency vehicle pre-emption equipment – GTT Opticom Infrared (IR) system.

4. Proposed Advanced Traffic Management System

In the near term (next 5), the City will continue to rely on their existing traffic signal control system. This system provides the desired functionality for traffic signal control. In the longer term (beyond the next 5 to 10 years), the City will migrate to an ATMS. The following provides a brief description of how the proposed ATMS works, and the follow sections describe how the existing traffic signal control system components will evolve to the ATMS.

The ATMS architecture is presented in **Exhibit 3**, including two components: central subsystem and field subsystem. The central and field subsystems are Ethernet connected, which could either be City-owned and/or leased. Ethernet is an effective solution to connect the roadside transportation applications due to its scalability, reliability, and cost. The central traffic signal control software and workstations are located in the Traffic Systems Management Centre. The field subsystem includes the field controllers and emergency vehicle pre-emption equipment. The emergency vehicle pre-emption equipment includes components installed on emergency vehicles, and at the roadside in the traffic signal control system cabinet. All devices used for the future system should be NTCIP compliant to make use of Ethernet communications systems.

Exhibit 3: Proposed ATMS Architecture



4.1 Traffic Signal Control System

Most of the City equipment (i.e. both Siemens MarcNx central software and Siemens/Eagle traffic signal controllers, except for the M50) are dated, and require replacement to comply with the NTCIP standard. As described above the main advantages of NTCIP are interoperability and interchangeability, along with the ability to use a modern Ethernet based communication system. More specifically, interchangeability and interoperability would mean that on the same Ethernet communication network the system would have:

- The ability to use multiple devices such as a traffic signal controller, and a variable message sign controller;
- Use the same device from different traffic signal control system vendors.

From a City perspective in the near term, the use of multiple devices is not desirable. The current City traffic operations strategies meet the operational needs of the City. Similarly, using NTCIP to support multiple brand controllers is not desirable to the City. The City and County use a maintenance contractor, and have limited staff resources to operate and maintain the existing traffic signal control system. There is considerable expertise required to operate and maintain a traffic signal control system. As is common in many medium-sized municipalities, it is more desirable to operate a single controller brand, which allows staff to focus on one controller type. As a result, the main benefit of NTCIP to the City of Sarnia is the ability to use an Ethernet communication system, and industry standard communication equipment.

The latest Siemens traffic signal control system central software is the Tactics central software, and the latest traffic signal controller is the M50. Note that the M50 is a quasi-ATC standard-based controller. Siemens has released a new ATC compliant controller called the SITRAFFIC Sphere, which uses the same operating logic as the M50 controller. The Tactics central software and the M50 controller are a future migration path to an Advanced Traffic Management System (ATMS) for advanced traffic operations.

Formerly, Tacel Ltd was the distributor of the Siemens products to the City. Tacel staff provide excellent customer support to the City as part of their product support. Tacel now distributes the Intelight traffic signal controllers and central software. The specific Intelight products of interest to the City are their MaxTime traffic signal control system software, and NEMA X-Series controllers (NTCIP compliant). These products are equivalent to the Siemens products (Tactics central software and M50 controller).

After careful consideration by City staff, they have elected to continue to use Tacel products due to the high quality of customer service, and the functionality of the Intelight products. For the foreseeable future this means that the maintenance contractor and City staff will need to work with two controller brands. Ultimately the older Siemens controllers will be replaced.

The existing cabinets are NEMA TS1 standard, which is compatible with the latest controllers (both Siemens and Intelight). This means that the City can replace existing Siemens controllers with Intelight controllers, while using the existing cabinets. A careful review of the cabinets is required to determine whether the existing cabinet should be reused or replaced.

The City now procures NEMA TS2 Type 2 controller cabinet assemblies. This standard allows the City to make use of the more modern malfunction management unit, and still maintain backwards compatibility with the NEMA TS1 controllers. Furthermore, the maintenance contractor and City staff are more familiar with the Type 2 wiring, which simplifies cabinet maintenance.

4.2 Communication System

The existing communications system is a low bandwidth application to support the proprietary protocols between the MarcNx central software and the traffic signal controllers. The speed of the traffic data communication is significantly slower than the Ethernet network, the latter commonly used in the industry. Enhancement of the communication network is required to support NTCIP.

In the longer term the City will evolve to an Ethernet communications network for traffic signal control. Many agencies are using the City Wide Area Network (WAN) as a transport mechanism for traffic control. City facilities become node sites for distribution to nearby signalized intersections. Often wireless communications technologies are used, such as WiMax and WiFi.

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4.3 Emergency Vehicle Pre-emption System

Although GTT offers a new radio-based emergency vehicle pre-emption system (i.e. Opticom GPS system), the existing Opticom IR system is proven to be a reliable system for over 30 years. There is no immediate need for the City to replace it with a new emergency radio-based system.

5. Recommendations

The following are the recommendations from this task:

-
- City staff continue to implement Intelight controllers, with distributor support from Tacel;
- City staff continue to procure NEMA TS2 Type 2 controller cabinet assemblies;
- City staff start to replace ageing Siemens controllers with Intelight controllers, where budgets and resources permit;
- The City continues to use the GTT Opticom IR system;
- In the longer term City staff investigate opportunities to use City-owned communication assets for traffic signal control;
- In the longer term City staff investigate the benefits of implementing an ATMS for traffic signal control.