APPENDIX 6

TRAFFIC SIGNAL CONTROL SYSTEM ASSESSMENT

Traffic Signal Control System Assessment
33874

Transportation Master Plan Update
City of Brantford

Prepared for City of Brantford
by IBI Group

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Table of Contents

1. Introduction

The City of Brantford retained IBI Group to update the Transportation Master Plan (TMP) prepared in 2007. Part of the TMP scope is to conduct an assessment of the existing traffic signal control system. The objective of this technical report is to review the existing traffic signal control system (i.e. central software, and field equipment) and to 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 detail and identifies market trends;
- **Section** 3 – presents an overview of the inventory of the existing traffic signal control system; and
- **Section Error! Reference source not found.** – identifies the next steps in the evolution of City’s traffic signal control system and communication system.

2. Traffic Signal Control System Standards

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

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. Today, most controller 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 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 Transportation Controller (ATC)

In June 2006, ATC Standard v5.2b was published as a formal standard of the ATC Joint Committee. The ATC is a current generation “Open Systems” controller standard. The ATC standards continue to be developed, and are maintained under the direction of the ATC Joint Committee which is made up of representatives from the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE) and the National Electrical Manufacturers Association (NEMA).

Since the initial release of ATC Standard v52.b, there have been multiple implementations and deployments of the standard. The ATC Working Group has continued to evolve the standard, based on feedback from ATC users. There were more than 100 comments submitted to the ATC Working Group during several years of deployment. As a result, additional corrections, clarifications and enhancements were discussed by the ATC WG and made to ATC 5201 V06 as part of this development. ATC 5201 v06.10 is now being distributed to the members of ITE and other standard development organizations (SDOs) for formal review. ATC 5201 v06.10 represents a significantly improved and clarified document over ATC Standard 5.2b.

The ATC standards are intended to provide an open architecture hardware and software platform that can support a wide variety of ITS applications. The standard establishes a common understanding of the specifications for an ATC for:

- Government agencies who specify and use ATC equipment;
- Manufacturers who produce ATC equipment;
- Software developers who develop application programs for ATC equipment; and
- The public who benefit from the application programs that run on ATC equipment and who directly or indirectly pays for these products.

The main component of the ATC is a small printed circuit board, call the “Engine Board”. The Engine Board has standardized connectors and pinout. The Engine Board is mad up of a central processing unit (CPU), Linux operating system (O/S), memory, external and internal interfaces, and other associated hardware necessary to create an embedded transportation computing platform. The Engine Board plugs into a “Host Module” which supplies power and physical connection to the input/output (I/O) facilities of the controller.

While the interface to the Engine Board is completely specified, the Host Module may be of various shapes and sizes to accommodate various transportation controller designs, and cabinet architectures. As a result, the engine board can be used in different types of transportation controllers (e.g. 2070 and NEMA). More importantly, the ATC can interface with NEMA and 2070 cabinet standards through the use of the standard controller-cabinet interface developed for the associate standard.

Most major traffic signal controller vendors have an ATC available to the market.

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.

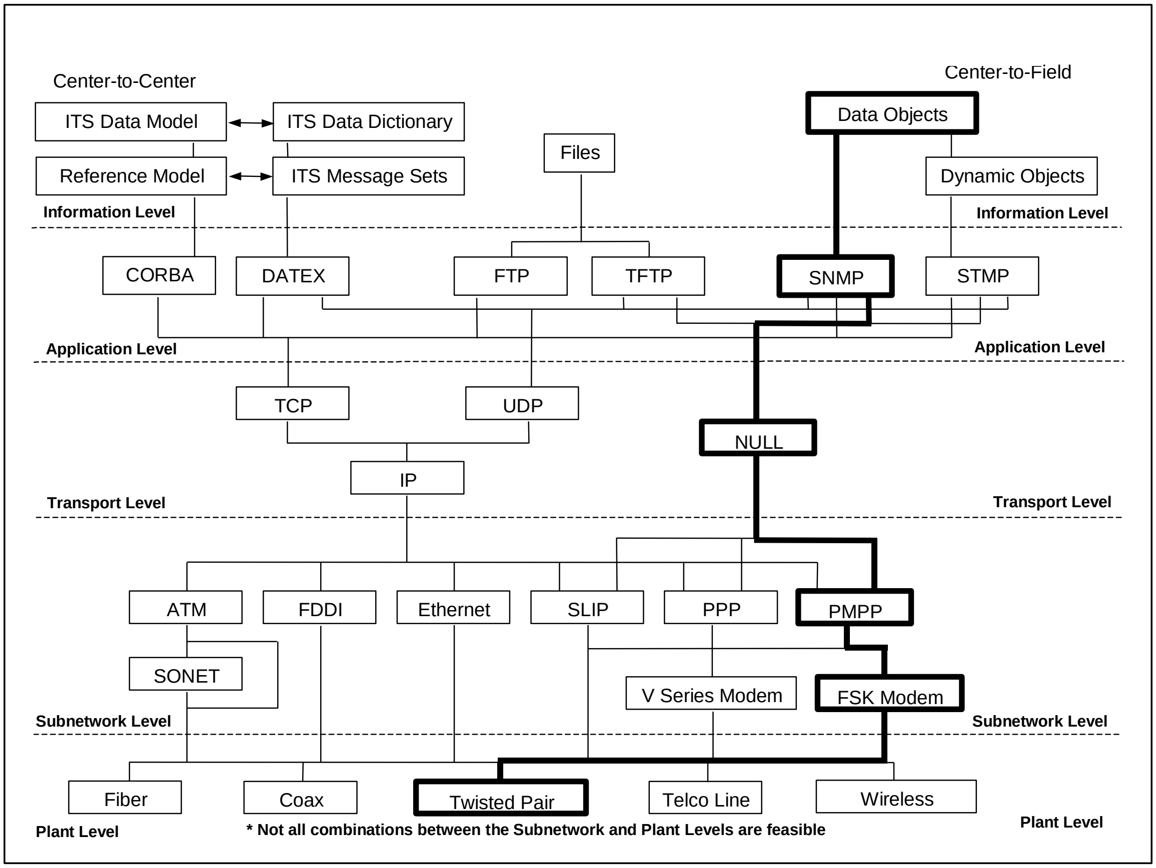
NTCIP encapsulates and specifies two different types of communications interfaces for ITS. The first type of interface is specified for communications between a central management system and multiple field devices for remote monitoring and control. This communications interface is referred to as ‘centre-to-field’. 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 1 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 1: 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).

2.4 Market Trends

The general market trends that we observe in the industry are:

- Use of broadband communication network for signal control, using industry standard communications protocol;
- The broadband communications protocol is not purpose-built for traffic signal control, but is part of a larger City-wide or Region-wide communications network;
- The broadband communications network is a mix of Agency-owned systems and leased systems;
- The NTCIP communications protocol is used for traffic signal control, and to operate on the broadband communications network;
- Some agencies use multiple-brand controllers with NTCIP, while others use just one controller brand;
- Many agencies are using ATC controllers instead of NEMA controllers;
- The ATC controllers are deployed in NEMA cabinets, often TS2 Type 1.

3. Inventory of Existing Equipment

For this assessment, the City staff provided the project team with an inventory of existing traffic signal control system, and challenges with the existing system. Details of the existing equipment are shown below.

- City controls approximately 135 signalized intersections;
- The system is a closed loop system with field masters;
- The City has 10 masters that communicate to the signalized intersections (one intersection is standalone);
- The controllers are Econolite ASC/2 and ASC/3;
- Approximately 100 controllers are ASC/2 and 35 controllers are ASC/3;
- The City is testing the new Econolite Cobalt ATC later this year;
- The central software is the Econolite Aries;
- The ASC/2 controller cabinet assemblies are NEMA TS1;
- The ASC/3 controller cabinet assemblies are NEMA TS2 Type 1;
- The City purchases their cabinets from Tacel;
- The existing communications system is Bell leased service from central to the master. City-owned twisted pair cable installed in conduit connects the master to the controllers;
- The City has in-house staff that are used to operate and maintain the existing signal system.

There are two main challenges with the existing traffic signal control system, namely: 1) failing communications system, and 2) vendor support of aging products. The Econolite Aries central software was originally developed in the 1980's, and has received many updates over the years. The Econolite ASC/2 controller was originally developed in the early 1990's. Both products are at the end of their life cycle, and from a technology perspective are obsolete. While both are reliable, they should be replaced as part of a new system implementation.

4. Future Advanced Traffic Management System

In the future the City will implement an ATMS for signal control, which is expandable to include other ITS elements such as timing of warning flashers, feedback from weather stations, monitoring of roadway traffic conditions, etc. The City will also expand their services to include County-owned signalized intersections.

The near term City objective is to implement a communications system that is reliable and expandable for both traffic operations. The City will hire a consultant to help design the future communications system. This system will use a mix of technologies, including wireless, fibre and leased services. The City anticipates completing the consultant assignment in 2014, and reporting to Council on the study findings, late 2014. The communication system deployment could commence in late 2014. The project completion date is dependent on funding and staff resources.

Following commencement of the communication system deployment, the City will prepare a Request for Proposal (RFP) to procure a new ATMS. The City could release the ATMS RFP as early as 2015. The release date is dependent on funding and staff resources.

Characteristics included in the ATMS RFP include:

- Broadband communications system that uses the Ethernet protocols;
- Use of NTCIP communication protocol for traffic signal control;
- Potentially supports multiple brand controllers through NTCIP Level 2 conformance;
- Potentially uses ATC controllers with a NEMA TS2 type 1 cabinet interface;
- Potentially includes the replacement of the existing Econolite ASC/2 controllers, while maintaining cabinet assemblies where feasible;
- Potentially interfaces with the existing Econolite ASC/3 controllers through the use of NTCIP;
- Potentially perform ITS functions beyond traffic signal control.

Overall the City of Brantford is using a standards-based approach for communication system design and ATMS procurement, and is following industry trends. This approach should serve the City well.