Wireless CCTV for Remote Arterial Applications
The Brock Road Incident Management System Case Study
Region of Durham, Ontario

Gregg Loane, P.Eng., IBI Group
Doug MacKay, P.Eng., P.T.O.E., Region of Durham Works Department

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ABSTRACT

The Brock Road Incident Management System is an arterial-based incident and traffic management system that will deploy ITS components to improve safety and traffic flow on Brock Road in the Region of Durham, Ontario. Brock Road (Regional Road 1) is a key connector between Highways 401 and 407 ETR in the City of Pickering, east of Toronto. It is particularly sensitive to traffic disruptions on Highway 401, which serves as the primary commuter route into the City of Toronto from the east.

The Brock Road Incident Management System will employ arterial-based CCTV, responsive traffic control, automated incident detection, and an advanced traveller information system to improve monitoring and detection capabilities, coordination of services on Brock Road, and dissemination of critical information amongst subscribers and the public. The primary purpose of the Incident Management System is to ease the impacts of increased congestion caused by incidents on Highway 401 and on Brock Road.

The first half of the paper reviews the intent of the arterial-based incident management system and the features it provides (responsive control, ATIS, CCTV, etc.). The second half of the paper focuses on the 'lessons learned' in the application of wireless CCTV technologies for the rural portion of this incident management system. Challenges in coordinating the actions and facilities of the local telecommunications providers, combined with long wireless links and problematic set-ups to make a wireless solution inappropriate given the proposed schedule and budget. The paper demonstrates how to identify the full costs and potential risks associated with wireless applications.

The paper concludes with a summary of the lessons learned in Durham's consideration of a wireless CCTV solution for arterial incident / traffic management systems.

1. INTRODUCTION

The Brock Road Incident Management System is an arterial-based incident management system currently under development by the Regional Municipality of Durham. It incorporates CCTV, a central (urban) Advanced Traffic Management System (ATMS) with responsive control, and an Advanced Traveller Information System (ATIS) to better manage the arterial road network when major incidents divert traffic from the adjacent provincial freeway network. As part of the design effort for the Brock Road System, a wireless communication solution was considered to provide connectivity with CCTV camera sites that were in rural areas without appropriate landline services.

Wireless transmission provides a practical and cost-effective solution to locations where other options are not possible or where landline communications are impractical or too expensive. A typical wireless transmission system contains, among other equipment, transmitters, receivers and antennae. The current technology makes it possible to deliver an MPEG-2 or MPEG-4 format digital video at 30 frames per second. The wireless transmitters combined with video CODECs allow users to digitize and transmit analog video using the 802.11 standard. The 802.11 standard utilizes the 2.4 GHz and/or 5.8 GHz unlicensed range for wireless transmission. Some systems can transmit up to 30 km. The range of transmission depends on several aspects, such as availability of line-of-sight and the high gain transmission equipment used.

As wireless communication systems for CCTV mature, they become an increasingly attractive alternative as they hold significant potential for related benefits. Typical benefits include:

- Reduced cost of communications infrastructure (relative to trench and cable);
- Reduced reliance on local telecommunications carriers and reduced costs related to long-distance tariffs;
- Ability to communicate with more remote areas where landline services are not available;
- In areas of rapid urban development growth, wireless options are less prone to disruptions related to landline damage; and
- Ability to re-deploy the infrastructure if replaced by fibre optic cabling in the future.

As part of its Brock Road Incident Management System, the Region of Durham considered the deployment of wireless communications systems for the expansion of its CCTV subsystem into the rural areas that lack appropriate landline telecommunications alternatives.

The following report documents the results, lessons learned and reasoning behind the ultimate decision to not install a wireless communication system for the CCTV cameras on Brock Road.

2. THE BROCK ROAD INCIDENT MANAGEMENT SYSTEM

2.1 BACKGROUND

Located in the eastern part of the Greater Toronto Area (GTA), the Regional Municipality of Durham is one of Canada's fastest growing areas. A strong economy and land development has increased the Region's population to more than half a million, primarily concentrated along the lakeshore communities of Pickering, Ajax, Whitby and Oshawa. The Region has recently

published its Transportation Master Plan (TMP) that identifies infrastructure improvements required to accommodate the projected growth in traffic volumes. As part of the TMP, the Region has identified a need to better manage the Regional Road system at times when incidents on Highways 401 and 407 ETR divert traffic onto the parallel arterial routes. In addition, a recent Council-endorsed Community Strategic Plan identified transportation as one of the biggest issues facing the Region. The transportation objective for the plan states that it is "To strengthen and integrate the transportation system so that people can move easily around the Region and access other parts of the GTA and beyond."

Brock Road is a north-south arterial road located at the eastern terminus of Highway 407 ETR see Exhibit 1) in the City of Pickering. It currently serves as the key connection between Highway 401 and Highway 407 ETR, a distance of approximately 8.8 km. At Highway 401, Brock Road is six lanes wide and has an AADT of close to 40,000. North of Rossland Road, Brock Road is a two-lane wide rural road. This route reaches capacity during the peak periods under normal operating conditions. Brock Road is highly sensitive to increased diverted traffic volumes generated by incidents on the adjacent major east-west roadways.

The Region of Durham has a number of existing ITS systems in place to manage traffic flows within its jurisdiction. These include an urban traffic control system featuring traffic-responsive logic, CCTV monitoring of key intersections, and real-time traffic flow monitoring, housed in Durham's Traffic Operations Centre (TOC) in the Town of Whitby. The existing ITS systems are primarily concentrated in the urban areas where traffic conditions reflect some of the worst in the Region of Durham.

With the addition of the Brock Road Incident Management System to the Regional ITS infrastructure, the Region of Durham hopes to integrate and expand the functionality of its existing ITS systems to better manage traffic flows in the Brock Road corridor. Specifically, it is the objective of this study to enhance safety, reduce traveller delay, reduce emissions, reduce driver frustration, and foster increased interagency cooperation. If successful, the concepts deployed on Brock Road will be redeployed across the Region's arterial road network.

In September 2001, the Regional Municipality of Durham, in funding partnership with IBI Group, Fortran, Axsys System Integrators, and Guild Electric submitted a proposal under Transport Canada's *ITS Deployment and Integration Plan* initiative to deploy the first stages of the Brock Road Incident Management System. The proposal was successful, and IBI Group was retained

to conduct the design and Project Management for the deployment. Axsys was hired to complete the requisite communications design, and Fortran and Guild to deploy the Citilog automated incident detection system.

The components of the system will include:

- The development of a high-level ITS strategy outlining the desired level of deployment on the arterial road network in the short, medium and long term horizons;
- The integration of new CCTV cameras and new monitoring software into the Region's existing systems to better monitor conditions on Brock Road;
- Upgrade the Region's responsive control algorithms to take advantage of improved local and system detectors and ramp coordination;
- The implementation of a new Information Management System (called SMARTS), to be used primarily as an ATIS platform for disseminating incident information;
- The implementation of automated intersection incident detection (Citilog) at selected critical sites within the Brock Road corridor;
- A growth strategy and needs assessment for the Region's TOC that will allow it to be used most effectively for incident and broader traffic management purposes;
- A White Paper on the benefits of establishing inter-agency agreements on the sharing of traffic and incident information within the Region of Durham (e.g. establish communication / organizational protocols between the Region of Durham Works Department, Durham Regional Police Service, local transit agencies, etc.);
- The development of an Evaluation Procedure to determine the effectiveness of the Brock Road Incident Management System in reducing congestion related to major diversions from the adjacent freeway network; and
- A strategic review of the Region's communications infrastructure.

With the exception of the Citilog deployment, these design directions were not new in the ITS field. This was because a design principle for the project was to take technologies and processes that were proven through applications in the freeway operations environment and reapply them in an arterial network environment to determine their potential benefits.

The following sections highlight the efforts within three major 'streams of activity' for the Brock Road Incident Management System project. These include the: (a) CCTV expansion, (b) responsive control, and (c) central system / ATIS streams of activities.

2.2 CCTV EXPANSION

The objective in expanding the Region's CCTV network to provide critical-site coverage along Brock Road and to explore updated means of communication between these CCTV sites and the Region's TOC. As part of this exercise, CCTV field installations and related communications infrastructure were designed. A significant upgrade of the central systems used to monitor and control the Region's cameras was also developed and integrated with the Region's existing LAN network and new video wall apparatus.

Approximately 5 km of the Brock Road study area is rural in nature. With increased traffic growth and the area's role as a key link between freeways, two intersections in the rural area were deemed important for monitoring: Taunton Road and Highway 407 ETR (see Exhibit 2).

2.3 RESPONSIVE CONTROL

The Region of Durham currently employs responsive control in several areas within their jurisdiction. This stream of activity was to develop and implement traffic responsive plans that are specifically aimed at mitigating the arterial network impact of an incident occurring on Highway 401. To develop the traffic responsive plans, several incident scenarios that may occur on Highway 401 were identified. For each scenario, the number of vehicles that would be diverted onto Brock Road was modelled. Network impacts were assessed based on the anticipated destinations for the diverted motorists and existing capacity constraints within the network. Corresponding measures were then identified to mitigate these anticipated impacts. They included upgraded responsive control algorithms, improved local detection, and potential connectivity with the Provincial ATMS vehicle detection facilities for Highway 401 in the vicinity of Brock Road.

As part of this activity, an evaluation procedure was developed to quantify the effectiveness of the responsive control plans in reducing congestion during either normal operating or incident conditions related to major diversions from the adjacent freeway network. As of this writing, the evaluation component of the System is still underway.

2.4 THE INFORMATION MANAGEMENT SYSTEM (SMARTS)

Another objective of the project was to create a platform for the provision of traveller information that could be expanded at a later date to function as a full freeway-management-style ATMS platform. The specific features of the SMARTS system include:

- A GUI featuring a zoom-capable Durham Region network map based on the medium-to-higher order arterial road network;
- The ability to declare events (i.e. incidents, queues, and weather advisory) in the same manner as in a freeway environment;
- The ability to manage events (e.g. automatic and/or manual creation of email and fax response advisories);
- Expandable to include automated responses for any other dissemination tool (e.g. VMS, PDA, IVR, etc.);
- A capacity for remote access that facilitates third-party and after-hours operations; and
- Event logging for historical / statistical reporting

The Region currently does not have dedicated operators at the TOC and the hours of operation are limited to office hours only. The Region expects to expand the hours of operation concurrently with the development of a new TOC facility to include the peak periods in the near future. In the interim, to assist in the detection and confirmation of incidents, and the dissemination of incident information, the project also included a preliminary investigation into the use of 'external agencies' (e.g. Durham Police, local transit dispatchers, etc.) that could assist in populating the incident database.

3. THE WIRELESS COMMUNICATION DESIGN

In support of the Brock Road Incident Management objectives, the project was to design the CCTV field installations and related communications infrastructure required to effect operating CCTV installations for four locations along Brock Road. These were:

- Brock Road / Pickering Parkway;
- Brock Road / Rossland Road (3rd Concession)
- Brock road / Taunton Road (Regional Road 4)
- Brock Road / Highway 407 ETR

The Pickering Parkway site (see Exhibit 2) is to complement the two existing CCTV installations within the urban area of the corridor. The existing sites include Kingston Road (Highway 2) north of Highway 401 and Bayly Street (south of Highway 401). The remaining sites are in rural areas.

3.1 TELECOMMUNICATIONS OPTIONS

The Region's existing arterial-based CCTV installations (a total of ten) all communicate via ISDN lines back to the Control Centre. While this communication medium does not provide full-motion CCTV monitoring capability, the images coming back to the Region's TOC have always been considered more than sufficient for the purposes of monitoring general conditions at the subject sites.

The Region of Durham covers a geographically large area and the Regional Works Department has long been beleaguered by long-distance exchange boundaries that divide the urban area within Durham. Not surprisingly, Durham Works has long desired to find a communications alternative that would avoid these long distance tariffs. The strategic review of the Region's communications infrastructure (noted above) suggests that the long-term strategy is to combine Region-owned fibre and copper infrastructure with wireless connections where appropriate. Deploying Region-owned infrastructure concurrently with road reconstruction projects will allow the Region to gradually build this network.

To obtain the monitoring and control functionality desired for the Brock Road Incident Management System CCTV cameras, the potential to access high-speed leased circuits at the four sites identified above was investigated. In total, four communications options were considered:

(i) Fibre-optic Cable;

(ii) ISDN;

(iii) XDSL; and

(iv) Wireless Communication.

3.1.1 Fibre Optic Cable

Fibre cable is a strong solution to any communication design. It provides a relatively low maintenance solution along with high quality performance. The main drawback of the fibre approach is the high cost associated with construction of underground conduit plant, which may cost up to $60,000 per kilometre in tight spaces requiring lane closures.

There are major reconstruction plans for Brock Road between Highways 401 and the 407 ETR, including road widenings, a grade separation and realignment. These plans are still in the planning stages and work will likely not commence until after 2005. Currently there are no significant underground conduits that could house fibre optical cable along Brock Road. It is expected that the Region will take advantage of this reconstruction project in order to place underground ducts along Brock Road. Until that time, the fibre optic solution is deemed impractical and unaffordable. However, it will be included as part of the reconstruction project.

3.1.2 ISDN

The current CCTV installations on Brock Road at Kingston Road and at Bayly Street utilize ISDN services. A request was submitted to Bell Canada (the local landline carrier) to investigate the availability of ISDN services at the four proposed CCTV locations. This service was only available at the Pickering Parkway and Rossland Road sites. A one-time installation service charge per site of $224 would apply with a monthly rate for one microlink line costing $114.60 per site. Bell Canada would perform the installation.

This approach was deemed practical for these two sites. The leased nature of the service for the Rossland Road site was particularly well suited, as it will be replaced by the Durham-owned fibre connection upon reconstruction of Brock Road.

3.1.3 XDSL

The availability of DSL services was also investigated for all four locations. The result was that only the Pickering Parkway site has XDSL available. The following provides a general idea about the local costs of ADSL and HDSL:

ADSL: $300/mo. to achieve an 8 frame per second (fps) rate
HDSL: $750/mo. to achieve 15 fps

For an additional fee, the HDSL service could be enhanced to achieve 30 fps. Given the acceptable level service that could be obtained through the ISDN service, the incremental benefits to be derived from the DSL service (i.e. full motion video) could not justify these costs, particularly in light of the growing number of cameras in this area.

3.1.4 Wireless Communication

Since ISDN and XDSL were not available at the two northern intersections, the wireless option was studied in greater detail. Initially, there were high expectations that a wireless solution would be the desirable solution for these sites. As noted previously, there are future opportunities for a fibre connection along Brock Road. In the interim, a wireless communication option would provide the required connectivity to the two more remote sites. Later, when the connection is

switched to fibre, the wireless infrastructure could be redeployed at other sites. This option is explored further below.

3.2 WIRELESS DESIGN INVESTIGATIONS

Through the course of the wireless design, two configuration options were considered:

- *Option A* - Bringing all the video back to a central point on Brock Road at Kingston Road, where Telus Communication has a tower on the property currently owned and occupied by the Durham Regional Police Service (the 'Durham Police Tower", or 'Tower B'). From the "Durham Police Tower" a connection would be extended to the Durham TOC via a T1 leased circuit or DSL service (see Exhibit 2); or

- *Option B* - Bringing all the video back directly to the Durham TOC (see Exhibit 4).

The viability of a wireless approach for Durham would be predicated on two critical issues:

- Due to the financing schedule associated with the Federal funding support, the work had to be completed in a relatively short period of time (with a hard deadline); and
- The capital and operating costs of deployment must be reasonable relative to the benefits to be derived.

The initial step for a wireless design was to determine whether or not appropriate lines-of-sight would be available. Line-of-sight was not available between the proposed camera sites at Taunton Road and Highway 407 ETR and either of the Durham Police tower or the Durham TOC. Therefore, in both circumstances, it would be necessary to use an intermediate tower with line of sight to the two camera locations. For the budget and scheduling reasons noted above, it was necessary to find an appropriate existing wireless communications tower rather than install a new tower for the Region of Durham.

3.2.1 Option A - Design Considerations

To get line-of-sight back to Tower B, it was determined that the signals from these two camera sites could be routed via a Rogers Communications tower (Tower A in Exhibit 3) which had line-of-sight with Tower B (the Durham Police Tower).

Negotiations were opened with Rogers Communications to lease antennae mounting space on Tower A. Discussions with Rogers revealed that the cost of co-locating antennae on Tower A depended on the number of antennae to be used, the elevation of the antennae, as well as the size of the dishes. A preliminary estimate for this space lease was provided at approximately $5000 per year for one microwave antenna with a fee of about $100 for any additional antennae. The preliminary design called for three antennae on Tower A and possibly one or two on Tower B, depending on the final design recommendations. This resulted in an annual estimate of $5200 annually for the use of the space on Tower A.

Further, Rogers indicated that the towers may require a structural analysis to confirm they are capable of supporting the additional loads proposed. The cost related to the tower analysis (if required) was not established, but estimated in the $3000-5000 range.

These prices did not include installation at either the Tower A or Tower B ends of the transmission. Rogers' requirements stipulated that any activities associated with the antennae installation on their tower must be completed by Rogers using equipment procured under the Durham project. Rogers' contractors and staff would perform these activities, and consequently, the costs would be non-competitive.

Although Tower B is owned by Telus and leased by the Durham Police Services, costs, approvals and access were not anticipated to be issues of concern to the co-location of antennae on this tower due to a pre-existing working arrangement between Telus and the Region.

However, this avenue of investigation and related wireless configuration were ultimately abandoned when Rogers Communications broke off negotiations indicating that they were no longer prepared to offer leased space on their communications tower.

Regardless of the Rogers position, it had become probable that the capital and operating costs of these installations would be prohibitively high. These sites were effectively temporary installations over an approximate 5-year term, after which the transmission medium would be swapped for a new fibre connection installed as part of the proposed road reconstruction. The capital costs to deploy would include the wireless equipment, approximately $4000 in structural analysis, and the costs of installation and troubleshooting. The latter item was of particular concern. The risks associated with the cost uncertainty for troubleshooting threatened the relatively tight budget available for the exercise. In retrospect, once the annual operating cost of at least $5200 is added to the equation (which did not include maintenance), it seems almost certain that there would have been a decision to abandon this approach.

Prior to the Rogers decision, Durham Works and their representatives had spent considerable effort in pursuing this potential communications solution. While informative, this design exercise exhausted a considerable amount of project schedule time and left the Region with only a short period to develop an alternative communications plan for the two remote CCTV sites.

3.2.2 Option B - Design Consideration

The approach in Option B called for direct wireless connection from the two camera sites to the Region of Durham's TOC. This approach was first considered after the Rogers tower became unavailable and an alternate tower was identified (a Telus Communications tower identified as Tower C in Exhibit 4). It was hoped this option would help the Region avoid the long-distance tariffs applied to the proposed leased T1 line between the Durham Police tower and the Durham TOC, as stated in Option A.

Through coordination with Telus technical representatives on site, it was determined that the Tower C site had line-of-sight with the Durham TOC. However, this line-of-sight represented a significant wireless 'shot', or distance of approximately 15km. Signal path loss calculations were prepared but did not reveal any concerns regarding a significant degradation of the signal over that distance.

3.2.3 Decision to Not Install Wireless Communication

After a technical and comparative analysis (conducted by Axsys System Integrators and IBI Group) of the wireless solution relative to other alternatives, it was determined that the following factors would substantially reduce the long and short-term benefits for this system.

- The up-front costs of hardware, installation, and troubleshooting for a wireless system would be very high in comparison to other alternatives and relative to the budget.
- The antenna set-up for a 15 km shot can be difficult and take considerable time to complete. While establishing a wireless communications link over this distance is possible, there are typically significant hurdles to overcome with respect to the setup. Setup includes alignment and fine-tuning of the antennae, and troubleshooting of the signal until an acceptable transmission can be established. The installation of a free-license system with such a long wireless link would require a high-gain receiving antenna. Because there are no restrictions on wireless installations within 2.4 and 5.8 GHz bands, this could result in the installed system picking up other transmission signals in the area. Therefore overall, even if unencumbered by atmospheric or other interferences over this distance, this process could take significant time to complete satisfactorily, and may have resulted in unacceptable delays in the project.
- This scheduling concern was compounded for the subject location due to the working conditions associated with the use of the Telus tower. As with the Rogers tower noted earlier, Telus had a strict requirement that only Telus personnel, or their representative, would be permitted on the tower to work on the antennae. Should there be a prolonged period of system setup and troubleshooting, it would be necessary to pay Telus personnel or contractors to complete this work (if possible). The incentives for a third party to complete this work in an efficient time period, and to the satisfaction of the Region of Durham, are low. In the event of a prolonged setup period, would Telus staff continue to be available indefinitely? Would there be premiums to get them to commit to, and complete this work (to Durham's satisfaction) instead of more lucrative projects?
- The Telus restrictions on competitive installation contracts and a lack of control over Telus installation crews, would increase the cost, and not provide for a time-efficient installation; and
- Also, in terms of long-term maintenance, there were concerns that for each desired access to the tower and its base station equipment, permission would have to be sought from Telus. This restricted access to the Telus towers for maintenance and troubleshooting purposes would result in longer 'down time' at critical moments when a quick response is essential.

Through the investigations of Options A & B, it became clear that a wireless communications solution could be technically feasible, but would be beyond the budget and scheduling means of the Brock Road Incident Management System project. A hard project completion date loomed (March 2004), and as the Fall of 2003 drew to a close, it became clear that even if sufficient budget existed, and it were considered cost-beneficial to proceed, a wireless solution could not be completed in time. The small number of wireless towers in the area, the presence of high power hydro lines, and the geographical topology of the region further reduced the possibility of a long-term stable solution. Therefore, it was decided to stop any further investigations into a wireless communication solution and concentrate on other technologies that could be installed in the remaining time provided.

3.2.4 Alternative Design Directions

The two rural CCTV sites that were the focus of the wireless communication investigation are considered key monitoring locations within the overall Brock Road Incident Management System. While a wireless solution was deemed to be unsuitable within the context of the Brock

Road Incident Management System Project, the Region is determined to install CCTV cameras at these sites in the near future. Installation options within the context of the current project include:

- Do nothing at this time;
- Install a fixed camera, utilizing a low speed 56Kbps leased circuit, until the completion of the Brock Road widening. At that time, the availability of fibre optic cable will provide access to high-speed communications. A fixed overview camera solution was considered an attractive option given the low cost and temporary nature of the installation. The Region's current needs for the System place a higher priority on overview monitoring of general traffic conditions than on incident site management. Therefore, the issues surrounding low-speed control of a PTZ may be avoided by installing a fixed overview camera until such time as the fibre connection is complete. This would adequately meet the current operational needs at a lower cost.
- Notwithstanding the related concerns, it would be possible to install a wireless solution if not constrained by the Brock Road Incident Management System project schedule or budget. While a generally costly venture, this approach may open up potential for communications connectivity to the large rural areas that make up the majority of the Region of Durham.

As of this writing, the 'Do Nothing' option has been selected and the remaining associated budget has been reassigned to other aspects of the System deployment. These CCTV sites will instead be part of subsequent deployment activities for the on-going Brock Road Incident Management System development.

4. LESSONS LEARNED

The following lessons should be derived from the wireless CCTV communications design exercise for the Region of Durham's Brock Road Incident Management System.

Wireless applications hold significant promise for CCTV installations without adequate landline services. However, it is in precisely these locations that installation concerns, or difficult to anticipate costs may arise, such as:

- Insufficient line of sight requires the installation of a new tower, or the leasing of space on an existing private tower;
- There may not be an existing tower appropriately located to suit your needs;
- The telecommunications carrier may not allow access to the tower, and therefore, a leasing opportunity may not be possible; and
- The more remote sites may require longer wireless hops or 'shots', leading to a more difficult setup (i.e. cost and schedule).

Installing wireless equipment in a leased environment (telecomm operator tower versus a deployer-owned tower) introduces:

- Administrative overhead related to obtaining permission to access the base station and wireless equipment;

- Loss of maintenance control over owner's equipment;
- Cost implications associated with equipment installation by tower owner resources;
- Delays related to base station and tower access requiring tower-owner permission and resources; and
- Increased costs related to tower space leasing.

5. CONCLUSION

When considering the installation of a wireless communications option, the full costs associated with the installation may not be known until a certain amount of design work is complete. And while operating costs related to long distance tariffs may be eliminated, there may be other associated costs related to installation, integration / setup, and potential monthly lease and access costs, that must be carefully considered to establish the cost-effectiveness of a wireless communications system.

Exhibit 1 – Brock Road in Pickering, Ontario

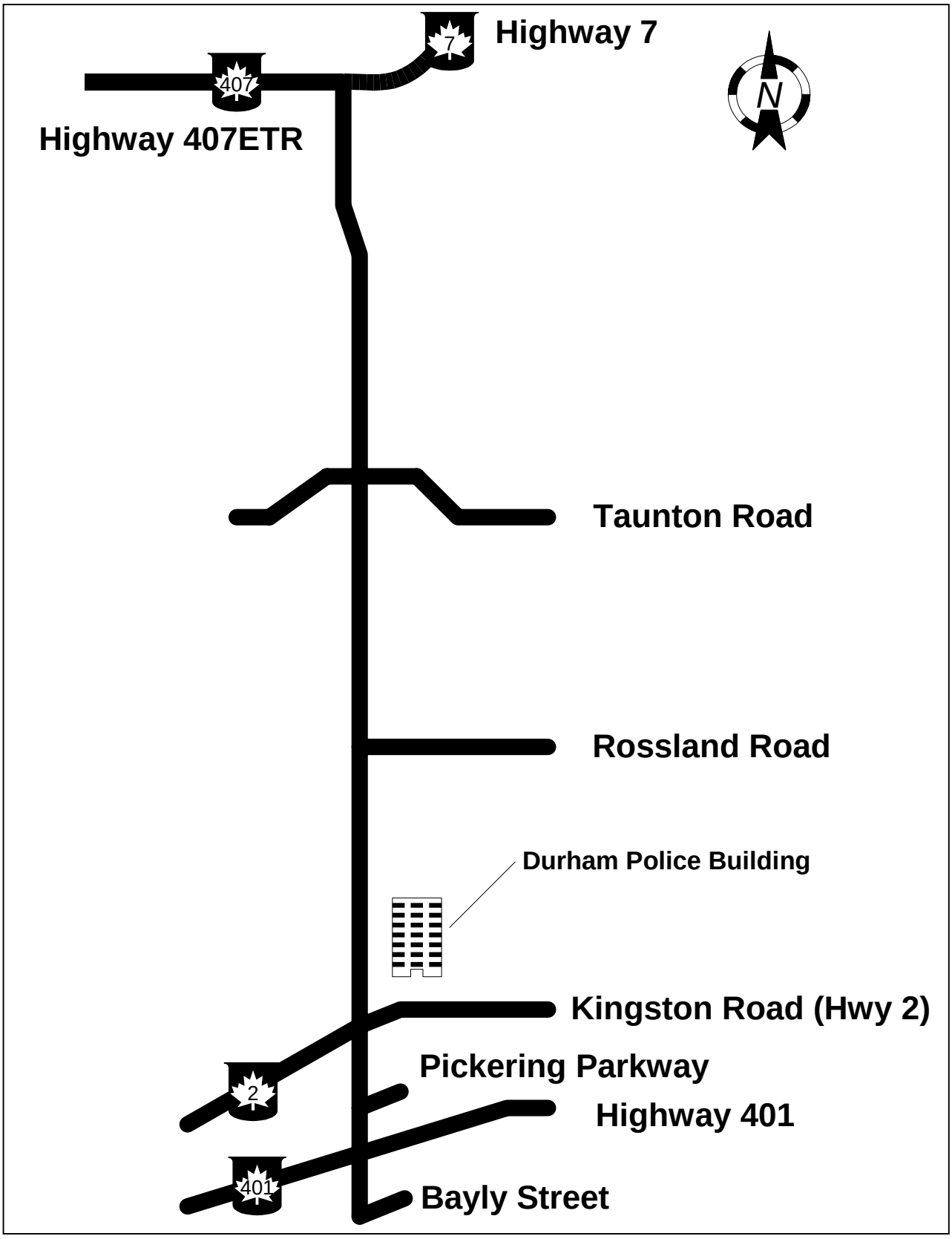

Exhibit 2 – Brock Road Project Limits

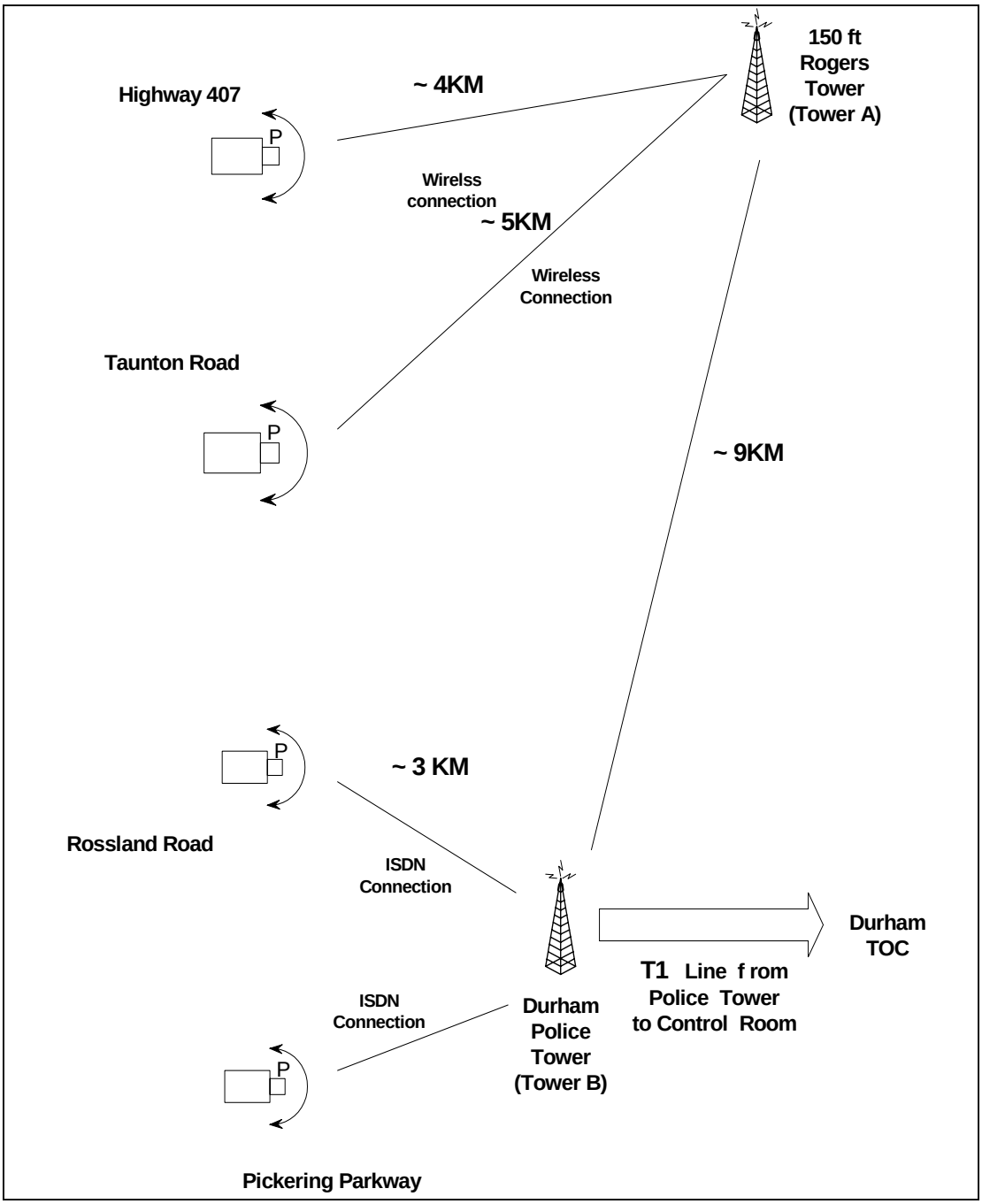

Exhibit 3 - Wireless Configuration Option A

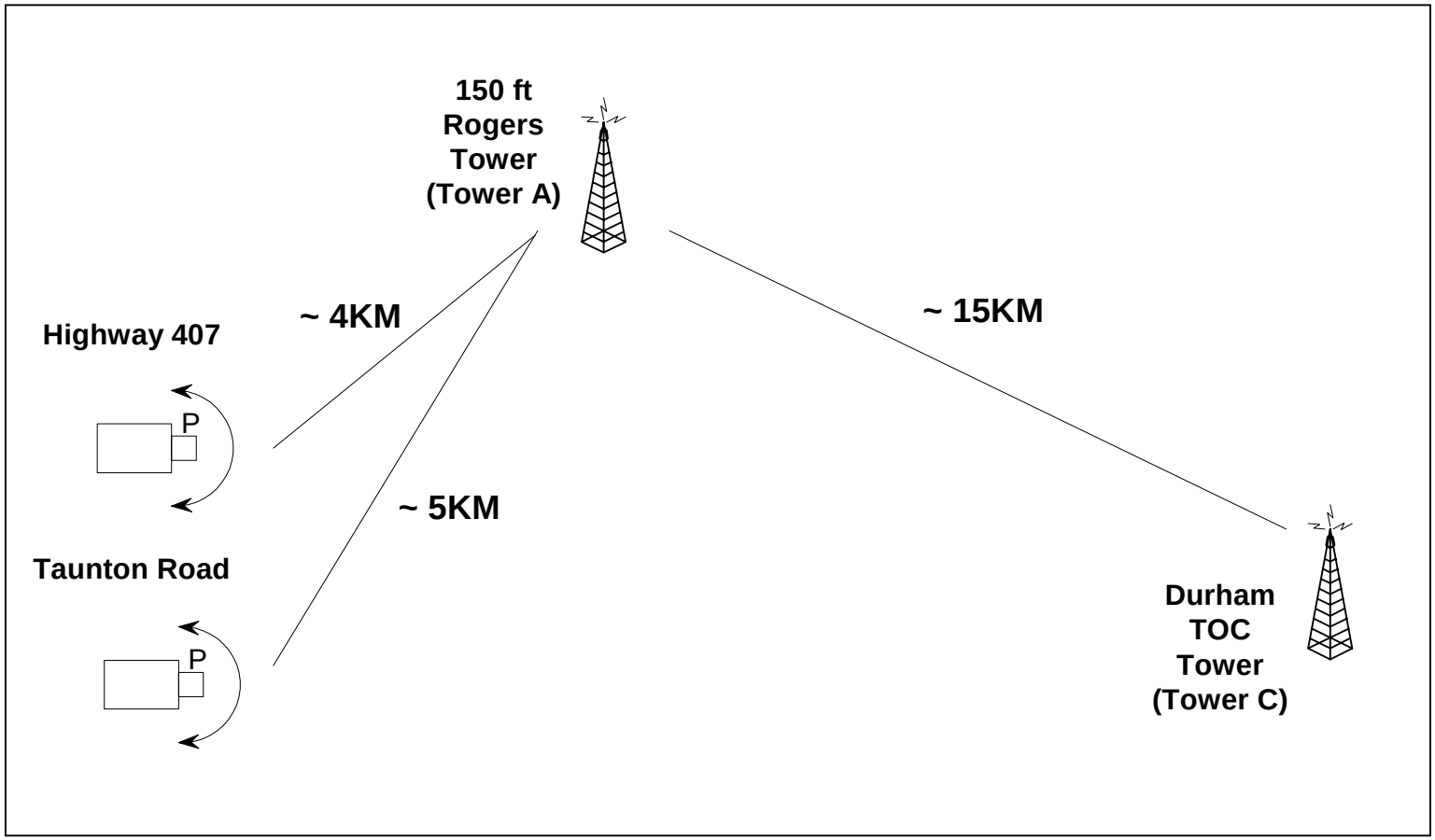

Exhibit 4 - Wireless Configuration Option B