Real-Time GPS Correction Service of the Canadian Active Control System

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BIOGRAPHY

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ABSTRACT

The real-time GPS correction (GPS· C) service is based on the Canadian Active Control System (CACS) network of Real-Time Active Control Points (RTACP) and a Real-Time Master Active Control Station (RTMACS). UNIX computer servers connected via land and satellite communication facilities are used for real-time GPS data acquisition and wide area GPS correction computation. The GPS· C corrections are verified at Integrity Monitoring Stations (IMS) and distributed in real-time via Virtual Active Control Points (VACP). The Real Time Application Platform (RTAP) software facilitates distributed process control, data communication, processing and distribution.

1. INTRODUCTION

The Canadian Active Control System (CACS) was established to improve the accuracy and efficiency of GPS positioning and to provide a direct access to the Canadian Spatial Reference System (CSRS). Precise GPS satellite ephemerides, clock corrections, and earth orientation parameters have been produced on a daily basis since 1992 with current precision of about 10 cm, 1 ns and 0.2 mas respectively. These CACS products facilitate geodetic positioning at the 1 cm level and single point positioning at the 1 metre level in post-processing with several days delay.

The Geodetic Survey Division (GSD) of Geomatics Canada, has developed a prototype real-time GPS Correction Service (GPS· C) based on the CACS stations shown in Figure 1. The system uses Hewlett-Packard UNIX servers, frame relay data communications and the Real-Time Application Platform (RTAP) enabling technology; add-on products and customized automation solutions have been provided by tesserNet Systems Inc. Operational tests have confirmed the viability of the system architecture, the selected platforms, data communication infrastructure and the application software technologies.

The real-time CACS is designed to facilitate continuous real-time positioning and navigation over Canada and adjacent areas. To meet these stringent requirements, the system incorporates state of the art hardware and communications technology. The system is also scaleable as far as data processing and area coverage are concerned. The technology is described in the sections which follow.

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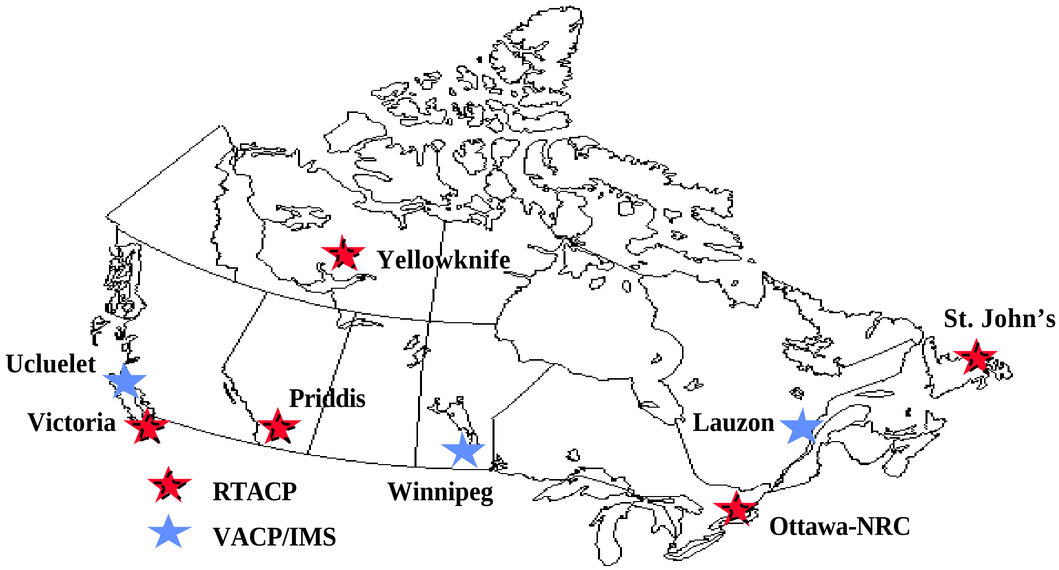

Figure 1: Real-Time CACS Prototype Network

2. PHYSICAL SYSTEM OVERVIEW

The physical system serves the following primary functions:

1. data collection, validation and communication at Real-Time Active Control Points (RTACP).

2. network data processing, management and GPS·C correction multicasting at the Real-Time Master Active Control Station (RTMACS).

3. GPS·C user interface at Virtual Active Control Points (VACP).

4. data integrity monitoring at Integrity Monitoring Stations (IMS).

Detail descriptions of the components are provided below.

2.1 RTACP

An RTACP consists of an HP E35 UNIX server and console, an RM-12 TurboRogue GPS receiver, an external frequency reference (rubidium, cesium or hydrogen maser), a meteorological station, a Cisco 2400 communications router, an uninterruptable power supply (UPS) and a power manager as illustrated in Figure 2. The RTACP is used to acquire, validate, store and forward data. In addition to the primary tasks, the RTACP also smoothes and decimates the 1 second GPS data to 30 second data points for post processing applications and applies corrective action in the event of exceptions. Exception events are logged and reported to the RTMACS.

2.2 RTMACS

The RTMACS consists of two HP E55 UNIX servers each with its own console, X-terminals, Cisco 2500 series routers, Local Area Network (LAN) interfaces and bridges, a redundant array of inexpensive disks (RAID) and a UPS in a high availability configuration as illustrated in Figure 3. The RTMACS is used to acquire GPS and meteorological data from all RTACPs. This data is verified and processed using predicted GPS orbits, resulting in GPS·C corrections including satellite clock corrections and an ionospheric vertical delay grid. These corrections, together with updates to broadcast and predicted ephemeris, are then available to all VACP and IMS stations within the wide area network via the multicasting TCP/IP service. The RTMACS also facilitates computer network management including the reception and transmission of diagnostic messages using Simple Network Management Protocol (SNMP).

The high availability configuration eliminates single points of failure. The CPUs are configured with HP M/C Service Guard software to switch over in the event of a failure of the primary CPU MACSA. A hot swap RAID disk is used for data storage to prevent loss of data and facilitate faulty disk replacement without operation interruption. Two routers and two LAN interfaces are available to provide redundant access to both the LAN and the WAN frame relay communications. In the event of a power failure a UPS maintains all critical components before diesel generator power is available.

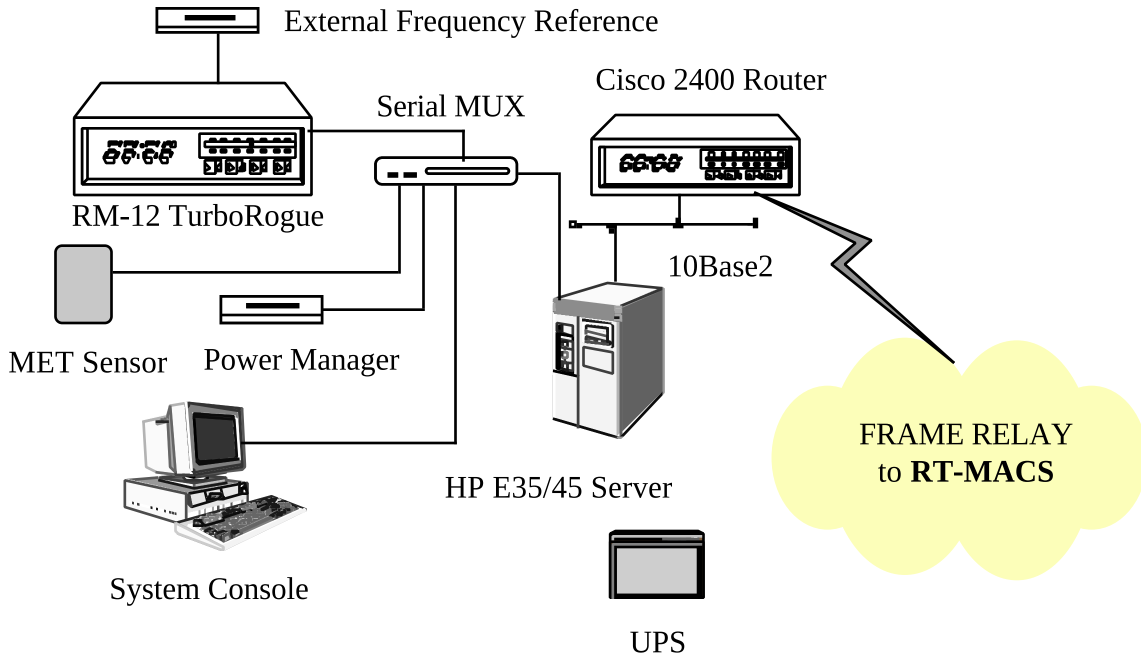

Figure 2: RTACP/IMS Configuration

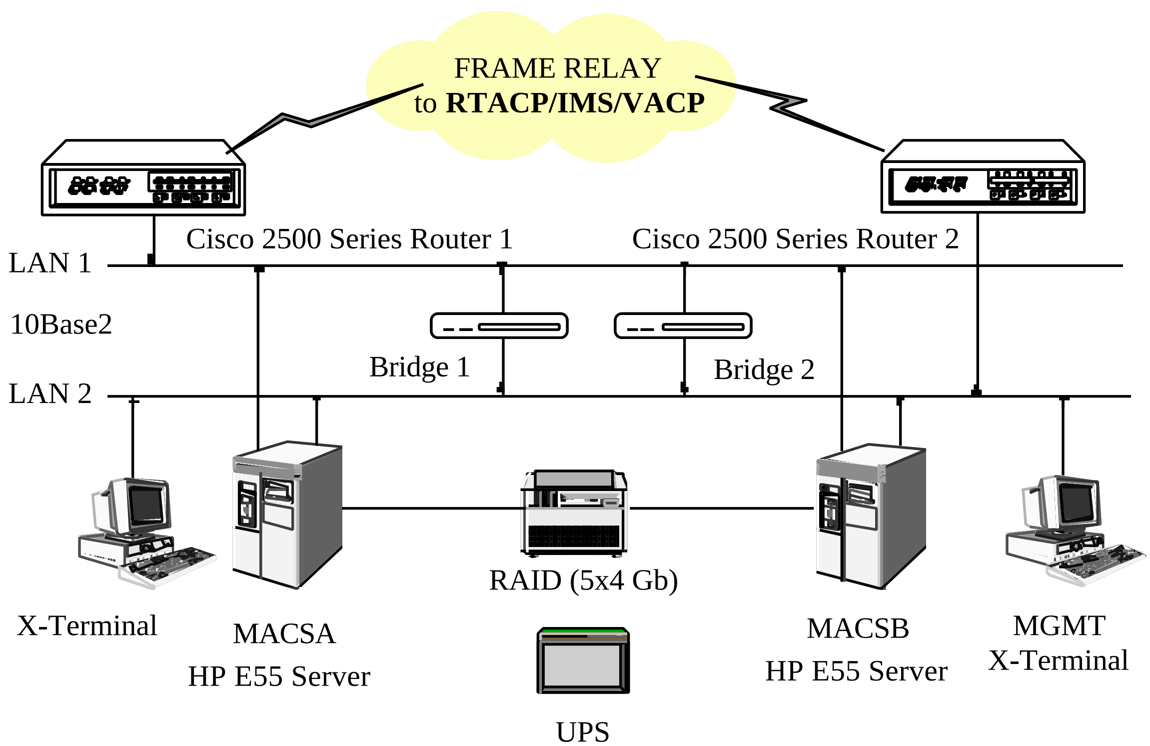

Figure 3: RTMACS Configuration

2.3 VACP

A VACP consists of an HP E35 UNIX server and console, a meteorological station, a Cisco 2400 communications router, an uninterruptable power supply (UPS) and a power manager. The VACP receives the GPS·C correction and ephemeris multicast from the RTMACS. Figure 4 illustrates the VACP configuration which is used as the primary distribution point of GPS·C corrections for service providers and users. The GPS·C corrections can be localized and update rates customized for multiple user communication interfaces (internet, datapac, modems, etc.). The VACP logs activity exceptions and reports these to the RTMACS.

2.4 IMS

An RTACP and IMS are similar in their physical design (Figure 2) and in addition to the functionality of an RTACP and a VACP, has the capability to monitor on a continuous basis the differences between the observed local GPS corrections and the GPS·C derived corrections. GPS observations from IMS stations are not included in the GPS·C processing to provide independent real-time quality control of the integrity of the GPS·C service which is reported to the RTMACS. IMS stations also provide standby RTACP capability since converting an IMS into an RTACP is a matter of changing configuration flags within the RTAP database.

In the event of an RTACP failure, the nearest IMS can be turned into an RTACP thereby minimizing the impact of such failures on the GPS·C service.

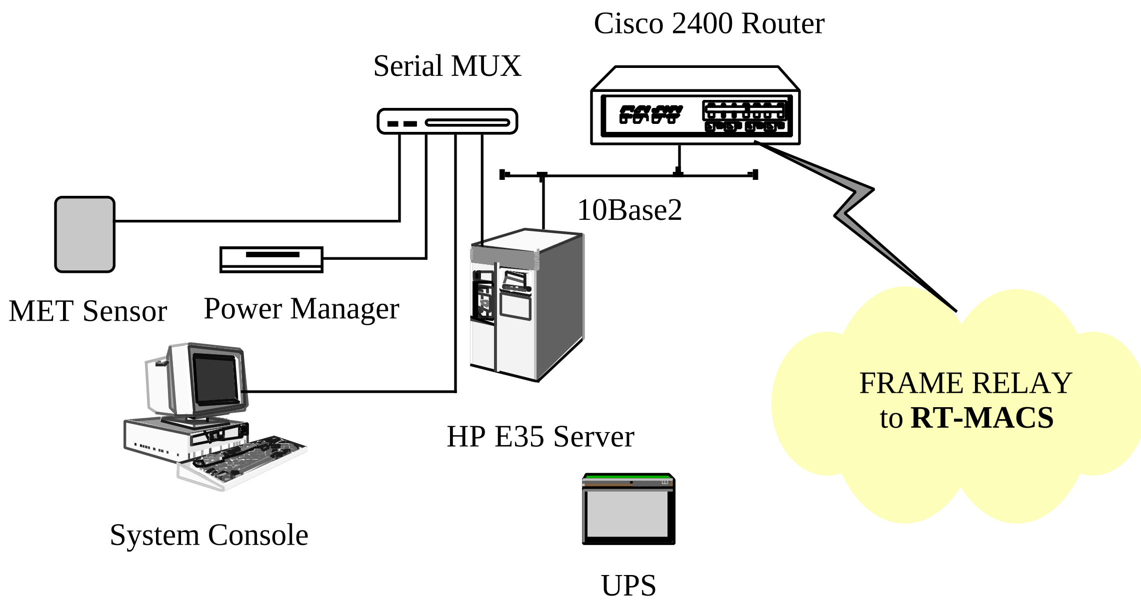

Figure 4: VACP Configuration

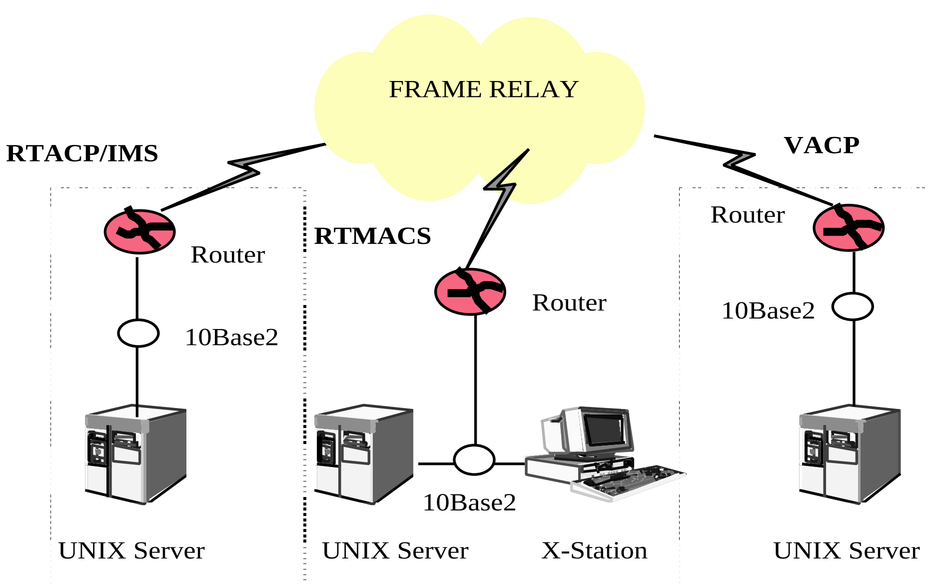

Figure 5: CACS Wide Area Network Topology

3. CACS COMPUTER NETWORK COMMUNICATIONS

Frame relay is used as the communications media for both data collection and GPS·C correction distribution. Frame relay has become the standard telecommunications service for Wide-Area Network (WAN) connectivity by maximizing bandwidth and minimizing costs. Optional data multicasting is used at the RTMACS for data distribution to keep bandwidth constant regardless of the number of receiving stations. The committed information rate (CIR) and data prioritizing features provide for optimization of WAN links in the CACS network. Figure 5 illustrates the real-time network topology.

4. REAL-TIME CACS SYSTEM INTEGRATION

The end to end data processing within the CACS network is based on the Real-Time Application Platform (RTAP). Data collection, processing and distribution is accomplished using this industrial process control tool which incorporates the following features:

a) A real-time database designed to model the physical nature of the application in order to store and process data using customized solutions.

b) A scan task system for interfacing user hardware and appropriate device drivers. The scan system also handles data communications among network nodes using TCP (server/client) or UDP (multicasting) services.

c) A calculation engine to integrate customer software with the RTAP database. With the aid of carefully designed functional specifications, Geodetic Survey's existing post-processing software has been converted into the real-time environment.

d) An event manager to handle real-time events as they occur. Exceptions can be trapped, alarms triggered or automatic action taken.

e) A process scheduler to manage the startup, run time priority, interprocess communication and shutdown of the RTAP environment.

f) A time keeper to manage jobs to run either periodically or on command.

5. REAL-TIME CACS PERFORMANCE

Tests have been conducted on the Real-Time CACS prototype to gather critical performance information. The results confirm the viability of the system architecture, the selected platforms, data communication infrastructure and the application software technologies.
Each of the physical system components RTACP/IMS, RTMACS and VACP have been tested to ensure that all primary and secondary tasks function as designed and that the selected server platforms have sufficient resources to accommodate future growth.

Tests carried out using 1 second GPS data from five RTACPs have shown total processing and data communication delays between two to three seconds for the Canada wide network.