Intelligent Transportation Systems – towards integrated framework for traffic/transport telematics applications

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Abstract - This paper describes the experience gained in the design and implementation of DIstributed computers shared Memory telematics Environment (DIME) for Intelligent Transportation Systems. The DIME telematics system has been developed by the SIM group at The Nottingham Trent University, UK, and its prototype implementation has been deployed in the Nottingham Traffic Control Centre since 1997. The versatility of the original DIME system has stimulated subsequent development of various traffic telematics applications which, in turn, prompted investigation into a second-generation hierarchical DIME system.

I. INTRODUCTION

Intelligent traffic control systems (ITS) not only need to operate in real-time (e.g. concurrently with the occurrence of the traffic) but also need to be able to anticipate the evolution of the system state so as to support predictive control actions. Indeed many researchers have made it clear that the progression from the fixed control schemes (based on historic data) to adaptive control schemes (based on real-time data) can be abstracted as a progression from non-predictive to predictive strategies. The early versions of adaptive control systems, as typified by the Split, Cycle and Offset Optimisation Technique Urban Traffic Control (SCOOT UTC) system, were utilising traffic flow measurements (inductive loops) on the approaches to the signalised intersections. Based on that, short-term predictions of traffic queues could be afforded and the appropriate modification of split-, cycle- and offset of traffic signals were calculated. As the instrumentation of cities became more extensive, incorporating various speed sensors, CCTV, pollution monitors, public transport monitors, probe vehicles etc., there is an increasing potential for the development of high-quality longer-term traffic predictions. These predictions underpin the development of a new generation of techniques for optimisation/control/management of traffic and travel.

While in the context of early UTC systems it was justifiable to use centralised computing resources, the increasing number of heterogeneous sources of information imply the need for re-evaluating this approach. The various specialised information processing tasks cannot be accommodated on computing systems that were designed without taking this additional load into account. A natural framework for the development of such dynamically evolving traffic/transport telematics applications seems to be a distributed computing architecture. Moreover, it has been demonstrated, in other application fields, that hierarchically distributed systems have improved management and can collect and manage large amounts of data ([2], [5]). Furthermore, such systems have better reliability and fault tolerance. The hierarchical distribution of information and control implies system modularity, which helps the implementation and the geographical growth of the system, and supports the introduction of new technologies and the evolution of existing ones.

II. DIME-1 – SHORT INTRODUCTION, ADVANTAGES AND LIMITATIONS.

An increasing number of hierarchical traffic information systems nowadays have been designed, implemented and deployed on the basis of relatively not expensive networked computers. Indeed, modern computer technology provides us with powerful desktop computers capable of real-time operation in data- and communication-intensive applications; tasks, which to-date, have been confined to expensive multiprocessor workstations. With the increasing number of vertical real-time traffic applications it became clear that additional significant benefits can be obtained by facilitating free flow of on-line traffic and travel information to all participants in the traffic process. However, such interoperability has so far been precluded by the use of proprietary system integration solutions. The lowest common denominator of a simple file exchange between applications has effectively precluded building complex integrated traffic/travel management/information systems. The long list of users of on-line traffic/travel information starts with low-level short-term control systems (SCOOT), and includes such tasks as high-level traffic management, public transport management, emergency services scheduling through to provision of information to the mobile handsets of the ordinary commuters. The challenge addressed by the authors was the development of an integrative environment in which traffic, travel and control modules can be accommodated effortlessly through the use of industry standard communications while, at the same time, ensuring high reliability and efficiency of the integrative framework.

A. *SHORT INTRODUCTION TO DIME-1.*

After investigating several approaches (e.g. message-passing paradigm, shared memory paradigm) and identifying the amount and frequency of data usage by several on-line applications (such as simulators, GIS for transportation programs, control modules etc.), the authors presented the DIME-1 design in [1], [2], [8], [9]. The DIME-1 system can be described as distributed computers shared memory system based on the central server algorithm. In addition, DIME-1 provides special structures for high-volume on-line measurement data (short time frame data) and low volume (mainly program module's status and longer term prediction) data. The overall structure of the implemented system is shown on Fig 1. In this architecture there are two main on-line data suppliers – the bus control centre and the real-time traffic control centre. These data are subsequently processed (with the help of several, connected within DIME, computers) and delivered to the end users' – commuters on the move – mobile devices. At the same time optimised control feedback is provided for the control systems.

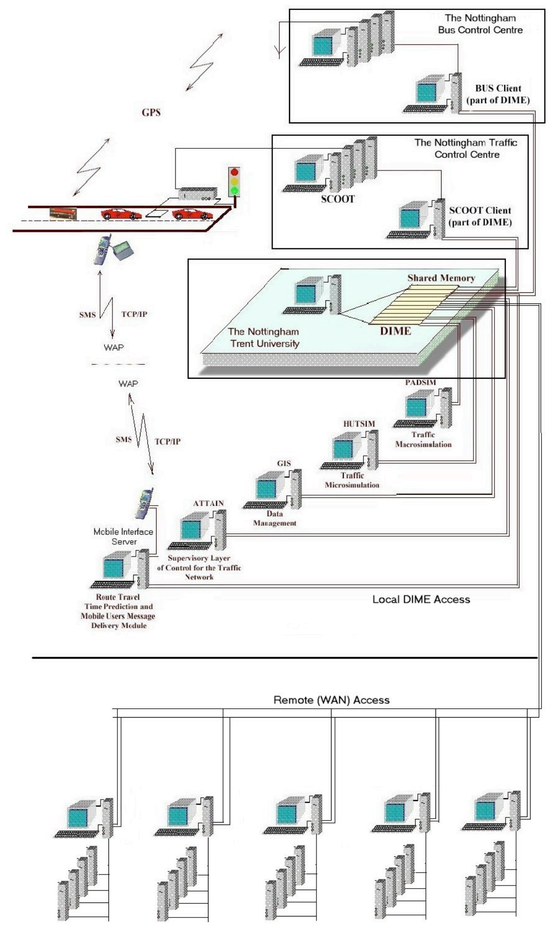

Fig1. DIME-1 overview.

The architecture shown has been implemented and currently accommodates between 5 and 15 different computers (depending on its use at that moment of time) running variety of operating systems (UNIX, Windows, EPOC, Windows CE, Linux). Each one of the programs connected to the system acts as a client of the system. Each client must link certain library to its code in order to obtain access to DIME-1. After entering the environment each client can create, delete, read and write memory structures and use the structures created by other clients and in this way exchange information with all other participants.

B. *ADVANTAGES OF DIME-1.*

The implementation of the DIME system showed several advantages:

1) Ease of adding new modules. With the help of the additional dynamic library, linked to the code of the client, every client has the functionality to retrieve or update the information required with a single procedure call.
2) The addition of new modules does not affect adversely any of the existing modules in the current system. Since every module runs on a separate computer there is no noticeable loss of performance of the other clients.
3) The low-level communication procedures provide fast and reliable TCP/IP data exchange with minimal overhead for housekeeping.

C. LIMITATIONS OF DIME-1.

At the same time the design showed several week points, which are addressed in the new DIME-2 design. The main deficiency of the system is the bottleneck problem typical for all central-server architectures. During the deployment of the system several observations have been made:

1. Not all created areas are needed to all participants in the system. This way 'local' only copies of the data are more suitable for data keeping and retrieval. This means that more than one data server is needed in the system.
2. Only one stream of high-volume data between the servers and many 'local' streams for each module requiring the data will help reduce the workload of the network and eventually increase the speed of data transmission.
3. While DIME-1 facilitates easy interchange of information between the modules that have already been configured, the system configuration can be a challenging task.

III. DESIGN OF THE DIME-2 HIERARCHICAL DISTRIBUTED COMPUTERS ENVIRONMENT

While the DIME-1 design can be characterised as a 'flat' communication module i.e. all clients have the same communication structure and the same communication link with the server, the DIME-2 design is truly hierarchical. The derivation of the structure of the hierarchical distributed ITS computing environment is based on the analysis of time frames associated with various measurements and control actions. Multiple access to lane-occupancy measurements, which are collected on a second-by-second basis, necessitates dedicated computing nodes together with a sufficiently broad communication path. These nodes assume the 'server' status with respect of various satellite applications. While some of these satellite applications are the end-users of the detailed measurement data, others perform granulation and integration of the various information items and make this processed information available to other users. In effect they become the 'second level servers', dealing with longer time-frame information. Such a node can be a client for the central server and, in turn, can be a second level server for the locally deployed applications. An example of that might be a server that integrates CCTV video frames with the traffic flow measurements and maintains suitable data structures that can be accessed by traffic management or journey planning applications. The dual functionality of the nodes in the DIME-2 system is illustrated on Fig.2.

The maintenance of a dictionary of active data structures on the distributed ITS system ensures that there is no unnecessary duplication of processing/storage/communication and ensures rational evolution of the system. Also, the usability of the DIME-2 system is enhanced through a clear 'dictionary view' of its functionality and user defined data structures to the application programs.

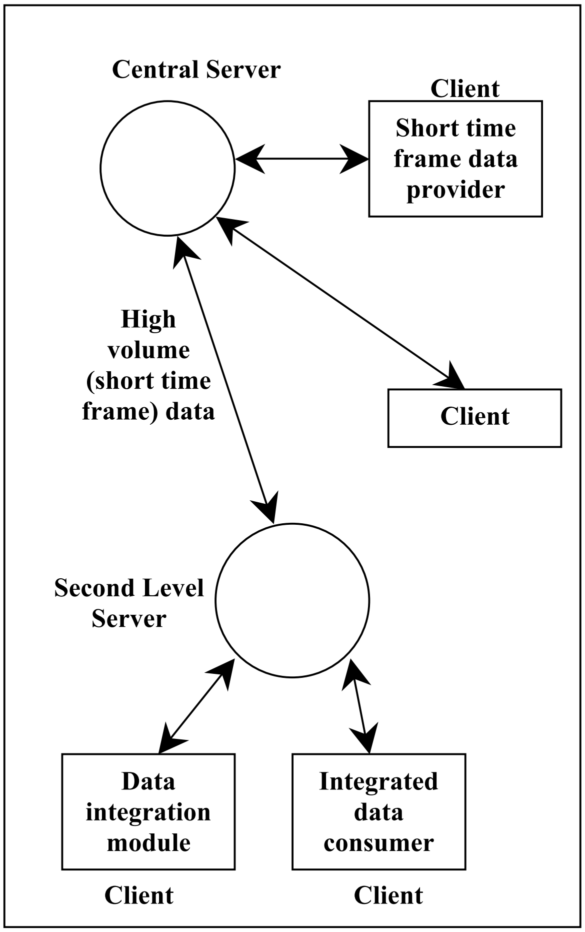

Fig2. Second level servers in DIME-2.

The inherent modularity of the original DIME system is preserved in the design of the DIME-2. A number of existing traffic telematics applications have been ported to the new framework. These include: macrosimulation prediction module PADSIM, real-time microsimulation module HUTSIM, turning movement coefficients estimation module and mobile (wireless) traffic information system etc.

IV. SUITABILITY OF DIME-2 FOR INTEGRATING TRAFFIC APPLICATIONS USING WIDE AREA NETWORK

The main challenge and motivation behind the DIME-2 is the integration of WAN-based traffic applications. More specifically, we address the problem of adding WAN-based nodes to the ITS distributed computing framework. Let us consider the case of delivering a high volume of data to several clients within the same IP domain. This is quite common since most organizations involve teams of people working on complementary ITS aspects. In this case it becomes natural to deploy a local master node, situated within the establishment, that maintains a single client connection with the central server. This is clearly a better solution than a 'flat' communication structure maintaining direct links between all clients and the DIME server. Moreover, the communication between the second level server and the client is much faster if performed in Local Area Network (LAN) environment.

V. CONCLUSIONS.

The DIME–2 system provides a viable solution to the problem of integration of diverse traffic and travel information systems. The shared memory design avoids the inefficiencies associated with low-level file sharing arrangements while overcoming the practical difficulties of integrating systems utilizing different computer architectures and different operating systems into a single communicating environment. The efficiency of the DIME environment is enhanced by its hierarchical design which minimizes data traffic over WAN while maximizing the benefits of high data throughput of the LAN.

The experiments with the implementation of the system showed that the presented architecture is capable of handling a high volume of SCOOT data traffic messages for the city of Nottingham. The system is now being further enhanced by the development of the web-based front end so that the configuration of the client-server interface can be performed from within a standard browser application. A possibility of an adaptive tuning of the structure of DIME-2 environment, so as to achieve an optimum system performance, is currently being investigated.

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