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**Integration of heterogeneous traffic and travel information through a combined
internet and mobile communications - FEASIBILITY STUDY**

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1.00 Background and objectives

1.01 Development of human-centred information systems that provide rich and accurate information on transport alternatives to general public has always been a key ingredient of any integrated transport policy. The Government White Paper 'A New Deal for Transport' (July 1998) places a special emphasis on the need to make **informed choices** by transportation research practitioners, decision makers and general public. Of these, the provision of information to general public represents a particularly difficult challenge. This is because the user information needs are not homogeneous; they depend on the type of journey that is being planned, the relative priorities (comfort, journey time, punctuality) and the individual preferences for information dissemination.

1.02 The research was focused on the assessment of technological feasibility of a comprehensive and accurate traffic and travel information system that promotes both urban sustainability and social inclusion. It is widely accepted that, on one hand, the distributed nature of traffic/travel information sources implies distributed computer architecture of the information system and, on the other hand, the need to provide access to information by the widest possible group of users implies the use of mobile telephone network as a universal communication media. However, while in principle the Internet communication can be used for linking the sources of information and the GSM telephones can be used for information dissemination, it is not clear what level of performance and responsiveness is attainable with such a distributed computing and communications system. The feasibility study built on our extensive experience gained with the real-time traffic information system (DIME); developed at NTU and deployed in a UTC environment (Nottingham Traffic Control Centre) for the past 5 years.

1.03 The results of this study serve to inform future research and development work on advanced traffic and travel telematics systems by offering the transportation research community an access to the state-of-the-art wireless travel information system and also an internet-based access to detailed traffic data. The development and evaluation of the advanced travel information system (ATTAIN) contributes to the promotion of social inclusion as well as beeing of value in the context of a broad range of telematics applications.

1.04 The project commenced on 1st March 2001 with the following research objectives:
   a) Investigation of the feasibility and performance of a distributed computing framework for the integration of multi-modal travel information in support of road- and public transport users as well as in support of high-level urban traffic management.
   b) Development of a reference system for future traffic/travel telematics applications regarding the assessment of their computing and telecommunications infrastructure.
   c) Contribution to the promotion of social inclusion through the development of the framework for integration and dissemination of information on multi-modal travel alternatives.

1.05 The above objectives have been achieved and enhanced by the additional study of information granulation as a means of achieving information abstraction. Although the granular computing study has been conducted here in the context of traffic and travel information systems it represents a general and very promising contribution to computer/cognitive science.

1.06 Given the success of the feasibility study in terms of the novel system design, its implementation and verification through extensive use by general public it is disappointing to report that the FIT Panel did not invite development of a research proposal that would build on the results of this study.

2.00 Research
The feasibility study was organised as a sequence of theoretical and software development stages alternating with the case study verifications of the developments. The case study system makes use of the combined Nottingham SCOOT traffic monitoring and control system and the NCT bus tracking system.

2.01 A new interprocess communication module has been developed as a generalisation of the existing DIME-1 framework. The module is capable of automatic detection of the output from the SCOOT system and, after analysing it, reconnecting to SCOOT if necessary. The new intelligent protocol monitors the message flow and if there are no messages form the inductive loops in the SCOOT system it issues the message-requesting commands again. This module is currently used to collect three different types of messages - M14, M08 and U06. All received messages are stored into the DIME system and saved on a hard disk (Bargiela, Peytchev, 2001).

2.02 A distributed computing systems with nodes at NTU, Nottingham Traffic Control Centre and Nottingham City Transport has been developed. The system can be augmented in a modular fashion and it provides a hardware framework of the Mark-2 hierarchical DIME system (Bargiela, Peytchev, 2001).

2.03 A master server for the traffic/travel data has been developed. The system provides access to shared data by client applications without requiring specification of the physical server addresses. The system will eventually consist of a dynamic configuration of servers, mirror servers and password requiring clients, coordinated by the master server. Load sharing algorithms for the master server are the subject of on-going research. The performance of the server has been assesses on a real-time micro-simulation study (Kosonen, Bargiela, 2001)

2.04 Investigation of the level of service that is afforded with alternative modes of transport has focused on the issue of flexible provision of information about public transport and assistance with planning travel. The mobile phone small message service (SMS) allows the user to choose starting and finishing points of a journey and to make appropriate travel requests. Users can specify their preferences of travel either by mode at the time of input or by shortest time when selecting which of the provided routes to take. The route to the requested location is evaluated using a combination of static, current and predicted data, including the physical layout of the urban network and the points of congestion. The integration of data concerning traffic flows, public transport and individual journey plans thus makes it possible to perform multi-modal optimisation of travel (Hartley, Bargiela, 2001).

2.05 Three shortest-path algorithms have been implemented to cater for travel by car, travel by public transport and multi-modal travel. The three shortest-path algorithms are modifications of Dijkstra's standard shortest-path algorithm, allowing for implementation with real-time data. User preferences have been considered either explicitly or implicitly by the software package. Further research and development will include user analysis of the suitability of the implementation within the context of multi-modal route guidance systems. This will aim at coping with volumes of user enquiries that are typical of real-life information systems (Hartley, Bargiela, 2001).

2.06 An analysis of interaction of the general public in Nottingham with the ATTAIN system has been undertaken as an extension of the original objective of the assessment of the system performance.

The 'mental model' of travel enquiries has been simplified by allowing reference to area names in addition to bus-stop codes that were originally used. The beneficial effect of this additional development was reflected in the largely increased volume of enquires.

2.07 A study of information granulation was undertaken in the context of analysis of urban traffic data. An analysis of data abstractions achieved with various granulation techniques revealed some interesting insights into the system operation that were not apparent when using 'standard' statistical and probabilistic approaches. It is argued that the methodology of information granulation (and more broadly granular computing) merits further study and is likely to be of fundamental value for future research. (Bargiela, 2001, Bargiela, Pedrycz, 2002a,b,c, Pedrycz, Bargiela, 2002)

3.00 Scientific achievements and major findings
There are three major deliverables resulting from this feasibility study, all of which were discussed during the FIT Panel Workshop meeting held in December 2001.

3.01 A system for Internet-based access to real-time traffic information. This will enable various traffic research groups to have access to a 'quarter-second resolution' real-time traffic data to support detailed investigations into the effectiveness of various traffic control policies. The structure of this system is presented in Figure 1.
Direct beneficiaries: research community and industrial collaborators.
(We have already provided an extensive log – some 600Mb - of detailed traffic data to transportation researchers at Imperial College working under direction of Dr Polack. The analysis of this data may provide very interesting insights into the nature of urban traffic flows. We hope that future support from EPSRC will allow us to make this facility available to a broad research community in the UK)
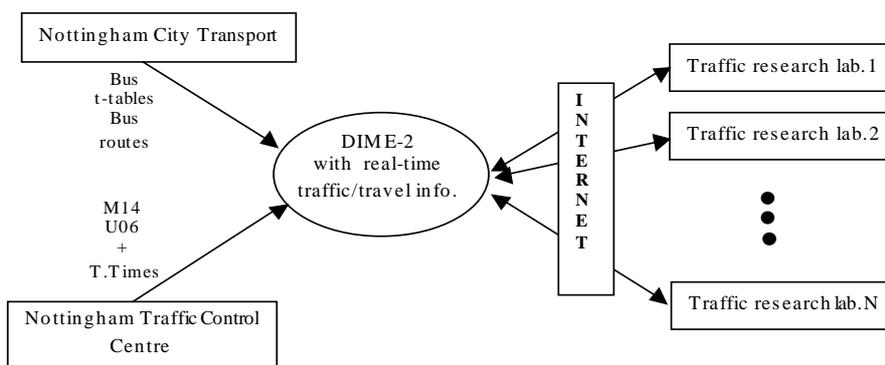

Figure 1. Structure of the Internet-based access to real-time traffic/travel data

3.02 An SMS-TEXT-based advanced travel information system (ATTAIN). The ATTAIN system integrates traffic and travel information and facilitates intelligent processing of general public requests for information about specific journeys. This helps potential public transport users to make informed decisions and also provides a valuable feedback (that was always difficult to obtain) to the transport providers on the travelling intentions of general public (thus underpinning rational development of public transport). The TEXT message based information service makes it possible to access travel information from all mobile phones without restricting information provision to specific information points only (bus journey planning at home rather than at a bus-stop). A general structure of this system is presented in Figure 2.
Direct beneficiaries: general public.
(The Mark-1 version of the ATTAIN system was released to general public in December 2001 and the enhanced Mark-2 version was released in February 2002. http://www.dcm.ntu.ac.uk/RTTS/)
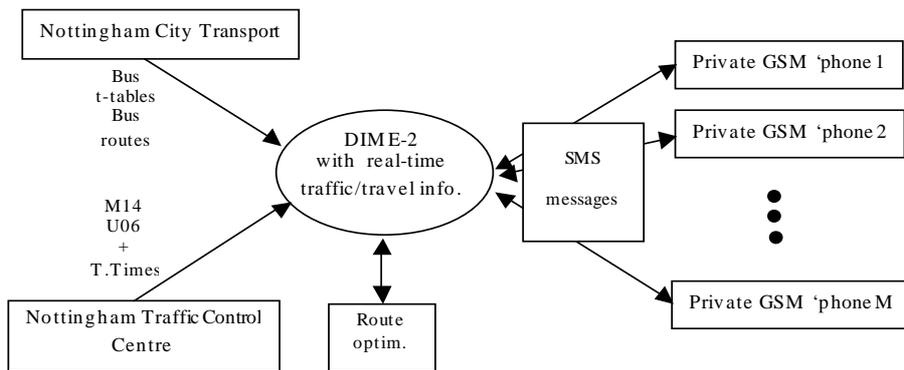
Figure 2. Structure of the SMS-TEXT-based traffic/travel information system

3.03   A bus-route display system. This software was primarily intended to provide support at the initial stages of setting-up the bus-route information system and was used as such. However, the software is also capable of providing a real-time bus location information (simulated in preparation for future deployment of the GPS system) as well as traffic delays on SCOOT-controlled roads. A sample of the current user interface is presented in Figure 3.

Direct beneficiaries: industrial collaborators (and general public if software is made available over the Internet)
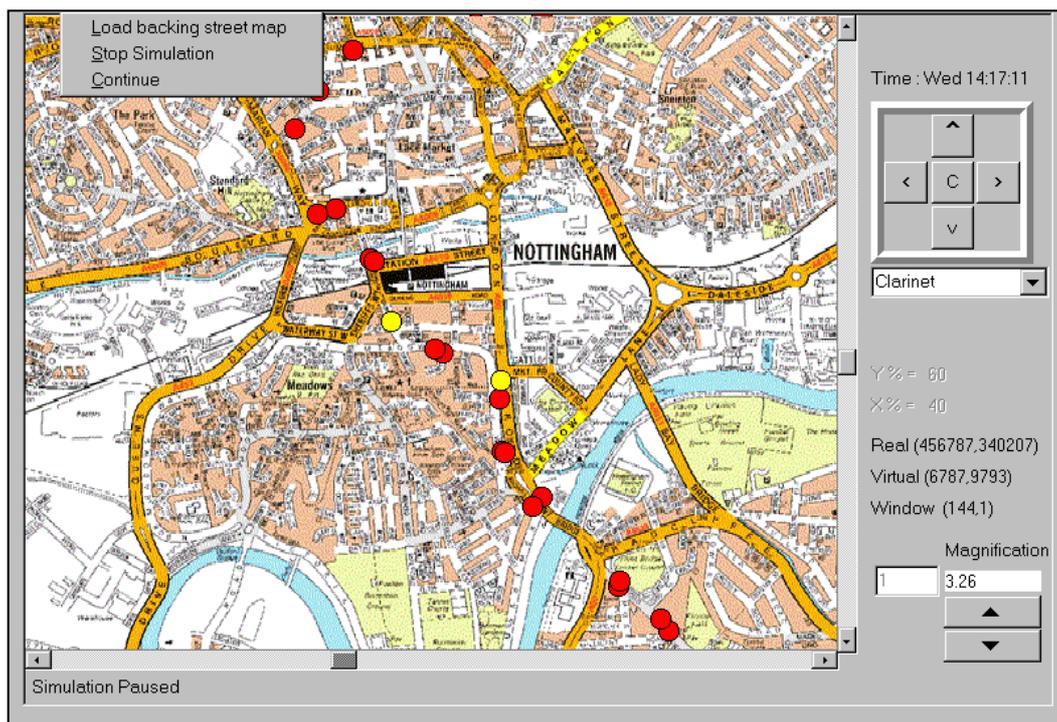

Figure 3. A sample user interface to the bus-location system

4.00 Principal conclusions and significance of results

4.01 All main objectives have been achieved in a way that goes considerably beyond original expectations. The new hierarchical distributed computing framework DIME-2 has not only been successfully tested in the laboratory environment at NTU but has been deployed at the Nottingham

Traffic Control Centre and the Nottingham City Transport. The system has been running on the continuous basis for the last 6 months of this project and is now scheduled to support the real-time GPS bus-location system currently being deployed in Nottingham. The wireless SMS-TEXT based travel information dissemination (ATTAIN system) has been integrated with the Internet-based DIME-2 and has proven its high performance in real-life trials by general public in Nottingham. This is a particularly significant result that underpins the novelty of the ATTAIN system.

4.02 The high-resolution traffic data collected from the Nottingham SCOOT system has proven to be a valuable research resource to our research peers at the Imperial College. An offer of research collaboration was made to all transportation research centres in UK through their invitation to the Open Workshop held on 6th November 2001 at NTU. The computing, telecommunications and system modelling expertise of the NTU team can be usefully combined with the expertise of our transportation research pears to open new unexplored research avenues. An example of such collaboration is the one pursued between the NTU and the Transportation Research Lab at the Helsinki of Technology (Kosonen, Bargiela, 2001).

4.03 The potential of the DIME-2 integrative framework has been confirmed using real-time traffic data and simulated bus location data that updates static bus timetable information. The data throughput was found to be dependent only on the efficiency of the physical link (wire-LAN/WAN, or radio-LAN/WAN) and was not constrained by the hierarchical management of the distributed computing resources.

4.04 The positive impact of the ATTAIN system on the travelling public (a contribution to the achievements of the Government's White Paper objectives) was measured by monitoring the number of enquiries that have been made to the ATTAIN system. An analysis of this data gives basis for making informed decisions about future development of the public transport provision. We were particularly pleased however by the comments from the general public urging us to extend the functionality of the ATTAIN system to all bus-routes in Nottingham and possibly to other transport modes.

5.00 Facilities and Software

5.01 The project made extensive use of four UNIX workstations available within the ISM group for research. A full set of the development support software has been provided internally thus helping to reduce the overall cost of the project. The DIME-1 distributed shared memory software, developed under a previous EPSRC grant, has served as a basis for the development of the hierarchical DIME-2 system.

5.02 Two items of computing hardware have been purchased as envisaged in the original project proposal. One Sun-Ultra workstation was used as an upgrade to the existing information server within the ISM group at NTU and the other workstation was used to upgrade the DIME server deployed at the Nottingham Traffic Control Centre (NTCC). The original workstation from the NTCC was re-deployed at the Nottingham City Transport as a server node.

5.03 Four GSM telephones were purchased at the beginning of the project and were extensively used in the ATTAIN system trials.

6.00 Dissemination and exploitation

6.01 Results of this study have been disseminated to both academic and industrial communities as well as being conveyed to general public. Detailed technical results were communicated in 3 conference papers, 3 journal papers and 2 book chapter contributions. A broad coverage of the research results and the discussion of the contributions of our industrial collaborators were provided during the Open

Workshop held at NTU on 6th November 2001. The Workshop was brought to the attention of all UK transportation research centres and the FIT Programme management. There were 9 presentations given at the Workshop; 4 by researchers from NTU (Prof. Bargiela, Dr.Hartley, Dr. Peytchev, Dr.Argile), 4 by the industrial collaborators: Nottingham Traffic Control Centre (Mr.Berry, Mr.Coggan), Nottingham City Transport (Mr.Denton), Motor Industry Research Association (MIRA)(Dr.Ward) and Nottingham Scientific Limited (Dr.Dumville) and 1 by a speaker representing the Greater Nottingham Transport Partnership (Mr. Roy).

6.02 Dissemination of the information about the ATTAIN system to general public has taken several forms. Initially, in December 2001, a press release was made to Nottingham Evening Post about the availability of the ATTAIN system for trials by general public. This generated a large public interest in the system and the feedback obtained proved invaluable in refining the subsequent version of the system. The release of the Mark-2 ATTAIN system was accompanied by two new press releases. This prompted interest of the local radio and the BBC TV. A news item about the ATTAIN system was broadcast on lunch-time TV and subsequently on 6-o'clock TV-news.

6.03 The Nottingham City Transport has publicised the ATTAIN system by placing posters on buses on the relevant bus-routes and printing a new edition of timetables that contained information about the ATTAIN trials. The NCT Travel Centre staff, dealing with telephone enquiries from general public, has been trained to provide guidance on the use of the ATTAIN system. The March edition of the NCT News, 40,000 copies print, also features the information about the stage-2 trials.

6.04 A set of www-pages is maintained by the investigators to provide further details about the project and to facilitate development of industrial and academic links.

7.00 Programme Management

7.01 The project was managed by the principal investigator who called weekly progress meetings attended by the co-investigators and the Research Fellow and the quarterly project review meetings attended by all parties involved in the project. An industrial exploitation plan was established at the early stage of the project. A meeting, involving all industrial collaborators, was held in March 2001. The second progress review meeting was held in July 2001 and a project Workshop was held in November 2001. The final project review meeting was held in January 2002.

7.02 The principal investigator has actively promoted the development of the new research opportunities in the area of granular computing (collaboration with Prof. Pedrycz, Canada) that is based on the results of this study. A possibility of commercial exploitation of the ATTAIN system is currently being investigated.

8.00 Publications

1. A. Bargiela, E. Peytchev, Intelligent transportation systems - towards integrated framework for traffic/transport telematics applications, IEEE Vehicular Technology Society conference, **VTC'01**, Atlantic City, Oct. 2001, pp.785-789.
2. J. Hartley, A. Bargiela, Decision Support for Planning Multi-Modal Urban Travel, Proc. European Simulation Symposium, **ESS'01**, Marseilles, Oct. 2001, pp.387-391.
3. I.Kosonen, A. Bargiela, Real-time environment for micro-simulation of urban traffic, Proc. European Simulation Symposium, **ESS'01**, Marseilles, Oct. 2001, pp.382-386.
4. Bargiela, A., Interval and ellipsoidal uncertainty models, **Granular Computing**, Physica Verlag, 2001, pp.23-57
5. Bargiela, A., Pedrycz, W., Recursive information granulation: Aggregation and Interpretation issues, **IEEE Transactions Systems Man and Cybernetics**, Vol. 32, 3, 2002, pp.358-371.
6. Pedrycz, W., Bargiela, A., Granular Clustering: A granular signature of data, **IEEE Transactions Systems Man and Cybernetics,** vol.32, 2, 2002, pp. 212-224.
7. Bargiela, A., Pedrycz, W., A model of granular data: a design problem with the Tchebyschev FCM, **Journal of Soft Computing**, 2001, vol. 6, pp.301-318.
8. Bargiela, A., Pedrycz, W., From numbers to information granules: A study of unsupervised learning and feature analysis, In: H. Bunke, A. Kandel (eds.) **Hybrid Methods in Pattern Recognition**, World Scientific, 2002, pp. 1-35.