WP	3
Project	Grid Middleware
NWG Partner	Lancaster University

Full Name	**Future Grid Middleware**

General Information

Funding	NWDA
Start/end date	Start October 2005 End Date September 2007
Collaborators	University of Manchester, University of Liverpool, CCLRC Daresbury
Resources	NWDA 2 person years
Authors	Prof Gordon Blair, Prof Geoff Coulson

Project Plan

Project Summary	WP3 as a whole addresses two key dimensions. The first dimension investigates short to medium term extensions to the WP2 infrastructure with a view to increasing usability of the software. The second dimension, which is the focus of Lancaster's Computer Science Dept, addresses longer-term issues relating to the very structure of Grid middleware to enable richer sets of applications to be supported. In more detail, this Lancaster CS work is focused on providing more flexible and extensible Grid middleware software with a view to supporting richer classes of application and also richer deployment environments. Lancaster CS has received support from the e-Science programme to develop a next generation middleware platform (in collaboration with others including Oxford Brookes University and UCL). In particular, they have investigated the use of reflection to provide more open, configurable, re-configurable and self-managing middleware platforms. A key element of this work which we refer to as *GridKit*, is to provide a more radical communications architecture based on the use of *overlays*. The GridKit approach supports the natural integration of (for example) peer-to-peer protocols and also support for alternative interaction styles such as publish-subscribe. The approach also supports configuration of the software for a variety of deployment environments including sensors interconnected by wireless ad-hoc networks, mobile devices using a variety of interconnection technologies depending on location, and more traditional large-scale cluster computers connected by high speed networks (our vision of what we call the *Divergent Grid*). As part of this, we are also investigating the use of Model-Driven Architecture tools to generate appropriate families of GridKit-based middleware from higher level specifications. In terms of the NW-GRID, Lancaster CS is building on the above-discussed work and investigating the support provided by our platform for a demanding application domain, i.e. that of water management, building on the experience of the consortium in Environmental Science. This area is a classic example of a 'Divergent Grid', featuring both large-scale simulation running on clusters and also a range of sensors embedded in the natural environment.

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Deliverables	**Middleware Development – 2 (project plan)** 1. Development of enhanced platform featuring a range of key services including service discovery and security. 2. Middleware evaluation projects, Support from ALL The deliverables from this work-package were clarified by the February 2007 as: *"The result of this work package should both be "prototype" middleware as well as a report covering a roadmap towards future middleware development. This deliverable should integrate Lancaster's Computing and Environmental Science departments GridKit work into/towards a core middleware architecture for a future NWG. "*

Progress and achievements

Progress towards deliverables	**Progress Report: Jun-Sept 05** In anticipation of the start of the work package beginning on the 1st of October, a series of meetings with users/partners have been set up to identify requirements for a pilot deployment of a Grid system augmented with a wireless sensor network. **Progress Report: Oct-Dec 05** In this early phase, the RA has mainly been working with colleagues in the Environmental Science Dept to develop an environmental informatics based scenario that is suitable for the development and demonstration of our Divergent Grid vision. The chosen scenario is situated in the area of flood management in a local river valley, and involves employing sensors that detect river flow rates, water table levels, rainfall levels, etc. The scenario is shaping up nicely and the current version is available in a draft report. As well as discussing the deployment of sensors on site in the river valley, the draft report also discusses the use of large-scale Grid computational facilities to predict flooding based on sensor reading and predictive models. In addition, a paper on this has been submitted to an embedded systems workshop ("GridStix: Supporting Flood Prediction using Embedded Hardware and Next Generation Grid Middleware", Danny Hughes, Phil Greenwood, Geoff Coulson, Gordon Blair [update: this has since been accepted]). We have also carried out initial work in developing hardware infrastructure. This has involved purchasing some hardware sensor platforms and looking into the best strategy for porting our existing GridKit to these platforms. The platform is mainly based on the Gumstix embedded computing platform from Waysmall Computers (http://gumstix.com/spexboards.html). Work is continuing primarily in task 2 (Infrastructure Development). This work will lead to a first version of a pilot deployable infrastructure. **Progress Report: Jan-March 06** The environmental informatics based deployment scenario mentioned in the previous report has been refined and essentially finalised. Initial implementation work has been carried out in terms of prototyping a Gumstix-based sensor node. This comprises a robust package powered with both a battery and solar panels. We are in the process of experimentally deploying a small number of these (not yet at the final deployment site) to determine their performance in terms of network connectivity, power management, and resilience to adverse weather conditions. We have already carried out some initial studies on the networking performance of these nodes in different weather conditions with submersion under water as an extreme case. We have also largely completed the port of the GridKit software to the sensor nodes. **Progress Report: April-June 06** Work has progressed on the development of the Gumstix-based sensor nodes. In particular, we have completed the port of the GridKit software to the sensor nodes and

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	have made further progress on pre-deployment pragmatic studies of network connectivity, power management, and weather proofing. Furthermore, we have developed a demo of the sensor network which we showed, with great success, to participants from a recent ubiquitous computing conference held at Lancaster. We have subsequently submitted this demo to two conferences (the Ubicomp conference and the SenSys conference [update: the demo has since been accepted at both of these events]) and produced a video of the demo. We have also produced a paper for the UK eScience All Hands Meeting (AHM). This received the 'best conference paper' award for AHM. **Progress Report: July-Sept 06** From July to September, we have made a number of advances in development: We have further developed the GridStix hardware platform by integrating the computational units with depth sensors. We have also prepared for deployment by installing the systems in weather-poof housings and on suitable mounts. Finally, we have expanded the GridStix platform to include a very low-power CPU and radio. This enables the GridStix to fall back to a less capable, 'personality' that consumes an order of magnitude less power during ambient conditions. **Progress Report: Oct-Dec 06** From October Lancaster CS has made a number of advances in the development of the GridStix platform for both depth and image-based flow monitoring. This includes the deployment of one camera-based GridStix and two depth-sensor-based GridStix, and the successful long-term field testing of solar-panels and other equipment. And successful acquisition of image-based flow data sets. We have also been involved in dissemination activities, which have resulted in coverage in the popular press including: The New Scientist, Wired Magazine and Slashdot. Finally, following a December project meeting, a proposal was developed and accepted to structure and forward the work of the partners. **Progress Report: Jan-March 07** In the period from January to March we have deployed the majority of the GridStix wireless sensor network hardware at the Cow Bridge site. At the current time, only three nodes remain to be deployed. We have collected significant volumes of image data, ultrasound flow data and also an increasing volume of depth data. In parallel, we have refined our depth and image logging hardware and software to be more accurate and better cope with long-term deployment in the field. More recently we have been focused on improving power management on the GridStix, which has to date achieved power savings of over 80%. We have also added separate real-time clock hardware to each node in order to improve the resilience of the system to power failure. We have also been involved in a range of dissemination and commercialization activities. A paper focusing on the requirements engineering side of the systems development has been submitted to the 2007 Requirements Engineering conference. Furthermore, we have been exploring potential commercialization of the GridStix platform for use predicting floods in Mumbai, India in collaboration with the U.S. based company 'RF Arrays'.
Major Scientific Highlights	➢ Development of a 'Divergent Grid' scenario in which a sensor network delivers real time sensor data in a tightly-coupled manner to a computational model running on a back-end computational resource (i.e. the NW Grid cluster resources). This scenario involves advanced sensor network concepts such as dynamically reconfiguration of sensor networks, self-repair of sensor networks, and dynamic trade-offs of computation and communication across both the sensor network and the back-end computational resource. ➢ Refinement of Lancaster's next-generation GridKit middleware to support a wireless sensor network (WSN) environment and the GridStix platform. ➢ First deployment of Grid middleware in a WSN environment and demonstration of the advantages of this approach in maintaining network resilience and high performance.

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	➢ Investigation of the use of overlay network technologies in a WSN setting as supported by GridKit's 'open overlays' abstraction. ➢ Development of a new and powerful sensing platform with both low-power and high-performance personalities – the GridStix platform. ➢ Pioneering use of novel sensor types (e.g. image-based flow measurement).
Publications/ Conferences	Papers published/submitted: ➢ Hughes, D., Greenwood, P., Coulson, G., Blair, G., Pappenberger, F., Smith, P., Beven. K., "GridStix: Supporting Flood Prediction using Embedded Hardware and Next Generation Grid Middleware", 4th IEEE International Workshop on Mobile Distributed Computing (MDC 2006), co-located with WoWMoM, 2006 (available at: http://www.comp.lancs.ac.uk/computing/users/geoff/Publications/MDC06.pdf). ➢ Coulson, G., "A 'Possible Future' for the Grid", Editorial article, Concurrency and Computation: Practice and Experience, to appear, 2006 (available at: http://www.comp.lancs.ac.uk/computing/users/geoff/Publications/CCPE06.pdf). ➢ Coulson, G., "Pervasive Grids: Integrating Sensor Networks into the Fixed Grid", invited paper, Proc. Euro-American Workshop on Middleware for Sensor Networks, International Conference on Distributed Computing in Sensor Systems (DCOSS '06), San Francisco, USA, June 18-20, 2006 (available at: http://www.comp.lancs.ac.uk/computing/users/geoff/Publications/DCOSS06.pdf). ➢ Hughes, D., Greenwood, P., Blair, G., Coulson, G., Pappenberger, F., Smith, P., Beven, K., "An Intelligent and Adaptable Grid-based Flood Monitoring and Warning System", Proc. UK eScience All Hands Meeting (AHM), East Midlands Conference Centre, 18th Sept 2006 (available at: http://www.comp.lancs.ac.uk/computing/users/geoff/Publications/AHM06.pdf). ➢ Greenwood P., Hughes D., Porter B., Grace P., Coulson G., Blair G., Taiani F., Pappenberger F., Smith P., Beven K., "Using a Grid-Enabled Wireless Sensor Network for Flood Management", published in the conference supplement of the demonstration session of the eighth International Conference on Ubiquitous Computing (Ubicomp '06), Orange County, USA, September 2006. (Available at: http://www.comp.lancs.ac.uk/computing/users/hughesdr/papers/ubicomp06.pdf). ➢ Greenwood P., Hughes D., Porter B., Grace P., Coulson G., Blair G., Taiani F., Pappenberger F., Smith P., Beven K., "Using Grid Technologies to Optimise a Wireless Sensor Network for Flood Management", published in the proceedings of the 4th ACM Conference on Embedded Networked Sensor Systems, November 2006 (available at: http://www.comp.lancs.ac.uk/computing/users/hughesdr/papers/sensys06.pdf). ➢ Grace P., Coulson G., Blair G., Porter B., Hughes D., to be published in the proceedings of the first International Workshop on Middleware for Sensor Networks (MidSens'06), Melbourne Australia, November 2006 (Available at: http://www.comp.lancs.ac.uk/computing/users/hughesdr/papers/midsens.pdf). ➢ Articles from the popular press describing our work can be found at: ➢ RCUK: http://www.rcuk.ac.uk/escience/news/flooding.asp. ➢ New Scientist: http://www.newscientisttech.com/article/dn10360 ➢ Wired Magazine: http://www.wired.com/science/discoveries/news/2006/10/71977 ➢ Slashdot: http://science.slashdot.org/article.pl?sid=06/10/24/2144206