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High-Performance Computing and Networking

Report of the HPCN Embedded Systems Industrial Working Group

" HPCN enables us to improve the way we work"

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Executive Summary

Computing systems are increasingly finding their place in a wide range of products ranging from consumer goods such as TV-sets or cars up to complex industrial systems such as advanced machine tools or the signalling of transport systems. These "embedded IT systems" have a dedicated function inside the complete system and are often not directly visible to the end-user. However, the embedded IT system is often instrumental in providing a more intelligent behaviour to the complete product, and at the same time in making it easier to use and safer. As a consequence, the embedded IT system will significantly contribute to the usability and the satisfaction of the user needs and, as such, will bring an important element of added value to products. The new HPCN architectures based on the parallel operation of commodity components offer high performances in terms of computing, storage and I/O bandwidths at moderate costs. They also offer the opportunity to easily adapt the number of processors to the requirements of each particular application (scalability). As a consequence, they offer important opportunities for increasing the intelligence of embedded systems and for widening the scope of their applications in user products, in industrial processes, and in infrastructure networks.

This document reports the findings of a group of experienced engineers from user companies in a number of different industrial sectors, who met to define common objectives of industry and actions leading to the exploitation of HPCN embedded systems in a wide variety of industrial sectors in the next 3 to 5 years.

At this point in time, there have been a number of successful applications of HPCN embedded systems, especially in leading-edge industry sectors. Actions proposed by the working group aim at facilitating a wider exploitation of these opportunities. An important factor to consider is the confidence in the technology and the awareness of its potential. It is proposed to launch a number of application demonstrators showing the feasibility and the advantage of HPCN embedded systems in a number of applications, especially in new application sectors. These actions could be complemented or coordinated with training actions for engineers and awareness actions for management.

As in the case of other IT systems, the decrease in the cost of components increases the emphasis on software aspects, in terms of increasing the demand on efficiency of software development and on preserving the engineering investment over different generations of hardware. The use of re-usable components and of standard methods, tools and programming environments allowing portability and scalability should be promoted in the application projects. In addition to these, it is also suggested to encourage the commercial offer of tools and the extension of such tools and methods to cover specific needs of HPCN embedded systems, such as those for developing real-time systems or for ensuring system reliability.

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1. INTRODUCTION

1.1 Objectives

The HPCN Embedded Systems Industrial Working Group, composed of experienced representatives of industries exploiting such systems in their products or industrial processes, met to establish industrial objectives in the use of HPCN embedded systems to improve their businesses. This report consigns the findings of the group.

The discussion was stimulated by a number of practical example applications from which a number of common points were collected. Obstacles to the exploitation of HPCN technology were analysed and actions were proposed to overcome these and to promote adoption in a wide range of industrial sectors. A constraint adopted by the working group was that the proposed actions should deliver results and business benefits within a timeframe of 3 to 5 years.

1.2 Background

The term of "embedded system" is used here to refer to a computing system dedicated to a pre-defined functionality inside a larger system. In a majority of cases, this computing system is submitted to real-time constraints, and represents only a fraction of the costs of the complete system. Embedded systems are included in a wide range of applications, from mass-market products such as TV-sets or cars to complex industrial processes such as the signalling of a railway network or the control of an intelligent machine tool. In many applications, the embedded system confers an intelligent behaviour to the complete product or process and brings an important fraction of the added value e.g. by giving it higher performance, making it easier to use and safer, or reducing environmental impact. In a growing number of embedded systems applications, the performance requirements have increased to a level which cannot be solved by conventional systems, be it in terms of computational power, I/O bandwidth and storage or in terms of other properties such as reliability, cost, weight or power consumption.

With the increase of performance and decrease in costs of standard microprocessors, IT hardware is increasingly based on commodity components. HPCN systems are exploiting these conditions to offer the highest performances at reduced cost based on multiple commodity components operating in parallel. These solutions provide substantial improvements with respect to conventional architectures both in terms of performance and of performance/cost ratio. This leap in performance offered by HPCN and the use of standard components allows developers to respond to higher application needs in a range of different application sectors as illustrated in Section 2, and also to expand the application potential into new business sectors. An additional advantage of parallel processors is that, under some conditions, a given system can easily be adapted to the requirements of a more demanding or less demanding problem by adapting the number of processors in the system. This characteristic is referred to as scalability.

While system hardware has benefited and will continue to benefit from major gains in performance/cost ratio, on the other hand, the software part of these systems has become increasingly complex and its development, long and costly. As a result, the emphasis on software and system architecture is increasing. The size of investments in application software development require that the software life-cycle be longer than that of the hardware. As a consequence, the application software should be portable, scalable, upgradable and easily maintainable, to maximise its reusability. A key measure ensuring longevity of application software is to follow standard system design and programming methods and to base the system design on standard components and interfaces. A proper exploitation of the scalability of parallel systems allows to cover a range of systems with the same technology, eventually scaling down to the embedded systems of tomorrow's mass market products.

2. Role and Contribution of HPCN Embedded Systems to Industry

2.1 General

With the increasing competitive pressures related to the opening and deregulation of markets, industry needs to offer increasingly complex products and to shorten the development cycles to be early on the market. New products have to be more intelligent, more powerful but at the same time easier to use, more reliable and safe, and their environmental impact must be reduced. HPCN offers the possibility to use more complex sensor-based subsystems and to use the information gathered by these to respond to some of these requirements.

HPCN embedded systems are also increasingly important in industrial production. Global changes such as the opening of markets and deregulation are promoting a change of industrial structure, with an emphasis on quality, cost, production flexibility and organisation of the production along vertical chains. HPCN will provide the necessary added intelligence to machine tools in flexible production chains, and will allow real-time visual inspection of 100% of production runs, allowing direct actions to control output quality. In the area of services, HPCN will contribute to offer more reliable service at reduced cost and delay.

HPCN embedded systems will also play a major role in the setup and operation of trans-European infrastructure networks. They will store and deliver vast amounts of data for services over the information infrastructure, and supervise thousands of sensors to monitor and control transport networks and to ensure continuity of service in power networks.

As we will see in a number of examples in the next subsection, all these application sectors will benefit of the advantages of HPCN in terms of performance, cost, size, power consumption. Other factors such as real-time operation, reliability, and reusability are also becoming increasingly important.

2.2 Examples of Contributions to Particular Applications

This section covers a number of examples of current or future uses of embedded systems in industry, and the objectives that could be reached within the timescale of 3 to 5 years. The order of the contributions is not representative of priorities in terms of HPCN. These examples include the exploitation of HPCN in final products, in equipment for industrial production or for service provision, and in trans-European infrastructure. They are representative of a large number of applications but do not intend to be exhaustive.

Automobiles

In the near future, an increasing number of intelligent functions will be added in cars. Initial functions include the provision of information to assist the driver; including road information and route planning, distance tracking to other vehicles, traffic sign recognition or obstacle detection. More intelligent functions will include the automatic reaction to this information, leading eventually to autonomous driving. All these functions are computationally very demanding and must operate within very short delays. For example, a computing power of 100 MFLOPS with constraints on cost, size, power consumption and reliability are needed in a car for lane detection.

Several initial functions are understood and are being implemented today. They will be introduced first on high-end cars or trucks, and will gradually be offered on a wider range of models. Further functions will be implemented incrementally as current price and technology boundaries evolve. For full functionality including all security measures, performances up to 2 to 3 orders of magnitude higher will be required. With an increasing number of responsibilities being shifted from the driver to the car systems, requirements in terms of reliability will also increase. This will require proper methods for designing, evaluating and demonstrating dependability.

The impact on society will be enormous in terms of the improvement in safety. It will also contribute to reduce traffic jams and pollution. Improvements in safety and operation will also be obtained by the implementation of HPCN embedded systems in other types of transport systems such as trains, aircraft or vessels.

Quality Control of Production

In most industrial sectors, a tested high quality of the products is becoming increasingly important for the competitive edge. This requires on-line quality inspection at different stages of the production chain and control of the process to maintain product quality in time or in face of variable input materials. Feasibility demonstration of visual inspection through cameras requires data pre-processing for pattern recognition with power requirements of the order of several 100s of MOPS and post processing with 20 to 100 MFLOPS. In order to cope with the speed of actual production lines, a performance increase of 1 to 3 orders of magnitude is required, in terms of computing power and in terms of input bandwidth. The scalability of HPCN systems is particularly useful for these applications in that the inspection systems can easily be adapted to increases in the production flow.

The full quality inspection of production output, as opposed to statistical testing, is important for quality control, and also for grading of intermediate materials. Proper grading has a direct impact on a better use of materials while optimising the quality of the end product. In the example of the wood industry, the quality grading of wood panels allows a quality improvement of the final product while optimising the use of raw material.

Document Reading and Processing

Millions of hand-written documents have to be read and processed every day to support service sectors like banking, medical insurance, or post. This requires the ability to read hand written text, to interpret the message read and to check its validity with a high accuracy and a very high throughput. Although reaching 100% reading accuracy may be illusory, every increase in recognition rate significantly reduces the operational costs of the service.

Hand writing is very individual, and shows regional and cultural differences; better accuracy can be reached when each system is tuned to the particular context of the application. The ability to train the system on the job using real problem cases is important to reduce the teaching time of the system. The computing power of today's installations is approximately 200 MFLOPS for voucher processing and 2 GFLOPS for address readers. An increase of processing power by 1 to 3 orders of magnitude is required to cope with the increasing requirements and to integrate further fault tolerance. The use of HPCN will result in a better quality of service: faster, cheaper, more reliable.

Hand-writing recognition systems could also be used for automatic on-line signature authentication, which would help reduce credit card misuse. An important off-line application exploiting similar technologies is the reading and interpretation of technical drawings.

Information infrastructure

The proposed information infrastructure is a revolution which will affect all areas of society, from the citizen, to industry and services. High-speed networks will be able to transmit animated information in real-time. It will allow the power of the largest supercomputers to be available on any desktop terminal connected to the network. Likely applications in the professional area include distance working, training, maintenance. Consumer services will include multi-media information, distance shopping, etc.. An important requirement for the provision of these services is the on-line availability of huge amounts of information accessible simultaneously by large numbers of users. These in turn require information servers or networks of servers, with very high storage capacities (10s of TeraBytes), to serve multiple clients simultaneously (1000s of users). Advanced data management techniques will be needed to handle the amount of data. The demands in terms of input/output bandwidths are very high, and must ensure time-synchronous delivery.

On the customer side, low-end multimedia terminals could be implemented with conventional technology, but high-end "set-top-boxes" will require very high computing power (several GFLOPS) at low cost. Initial prototypes will likely be built on the basis of parallel systems, and the system architecture and development methods used for these prototypes will be important for the later mass production using appropriate platforms.

Transport Networks

Transport networks like highways, railway, air traffic.. must accept increasing traffic load while at the same time they need to improve or maintain their safety record and the travel times. The control of such networks requires the processing of very large numbers of inputs from a variety of sensors. This requires high performance computing power with strict requirements on safety. For example, for the signalling of new generations of high-speed train systems, processing powers of the order of 100 MFLOPS are needed, together with methods to demonstrate reliability. Similar requirements can be found in control systems for air or road traffic.

The impact on society includes improvement of safety, the reduction of traffic jams and pollution, and the optimisation of throughput of the transport networks to optimise the utilisation of the investment.

Power generation and networks

Society depends on the quality and availability of electrical power. In case of failure of a component of the network, instant reaction is needed to ensure continuity of service and to minimise transients. The control of a high voltage switching station requires real-time systems handling 1000s of inputs, each with multiple read operations to reach time redundancy and short respond time (0,1 to 1 ms) are required. These systems also need to deal with "alarm overloads" in case of failures. Today's systems are limited to 10 to 100 MFLOPS due to the lack of the appropriate specification tools, to verify and validate reliability. The actual required processing power is estimated to be above 1 order of magnitude of that available today. Scalability is also important for these systems to tailor each implementation to the particular application.

Intelligent Machine Tools

Industry increasingly needs to be able to use its production lines for different versions of products, and to rapidly reorganise production facilities for new products. The response to these demands depends both on the organisation of the information structure of the company and on the use of production systems with more intelligence and autonomy. HPCN embedded systems will have an impact on these intelligent production systems which need to rely on processing of data from multiple intelligent sensors and on data fusion to tune their operation to the state of the process and to the environment. These operations have to cope with the speed of the production and hence require very large real-time computing power. More intelligence will be a crucial element of many other embedded systems to respond to improve functionalities of complex systems while making them easier to use or to integrate.

3. Facilitating a Wide Exploitation

The industrial chain leading to the deployment of embedded HPCN systems starts from the suppliers of microelectronics devices, through suppliers of systems and basic software, through IT application integrators and up to integrators of the complete systems, be they final products or production equipment. There are established strengths in Europe at most of the levels of this value-added chain; it is important to build on these and to expand the application potential of HPCN systems. The industrial application sectors had been limited to narrow leading-edge sectors such as aerospace in the 80's, but there is now a potential for addressing the needs of a wide range of business sectors. A wider exploitation of the potential in HPCN embedded systems can be facilitated by promoting targeted technical progress and by acting on non-technical factors.

Non-technical factors to increase the take-up of HPCN include improving the awareness of existing technologies and of their potential, and increasing the availability of trained personnel to exploit these technologies. The awareness of the capabilities and limitations of the technology addresses mainly the managerial level of IT system integrator companies. Managers need confidence in the technology in general. They must ensure cost efficient use of the technology, project feasibility, and maintainability and serviceability of the product. An important concern for managers is to reduce risks. There is hence always a reluctance to adopt a new technology until it has a proven track record. More examples of successful uses of HPCN in products and industrial processes should contribute to improve the visibility of the technology. Another factor affecting HPCN systems is that tools and software modules for the design and implementation of parallel systems are provided by little known companies. Many managers do not believe in continuity and quality of the support from these companies for items on which the key business of the company will depend.

The awareness of project engineers concerning the market offer should be increased. They must be able to choose among available products, tools and methods. Today, there are also too few companies and professionals who are able to conceive and manage HPCN based solutions to industrial embedded systems problems.

From a technological point of view, a wider use of HPCN embedded systems will also follow a reduction of the cost of developing HPCN-based embedded systems, and in a number of cases, an improvement of the performance or performance/cost ratio of HPCN systems available today. The cost of development of HPCN embedded systems solutions is quite high at the present time, in part because libraries of reusable software modules (both system and application software) are not generally available and supported by software houses judged as reliable. Most development tools addressing common needs such as real-time and reliable operation are not commercially available for parallel processors. Only research and study versions of such tools exist for this class of architectures. Methods to demonstrate system reliability criteria are lacking. These are needed for product certification tests in some areas before products can be operated or sold. Work on basic software and software components is especially important since it has a multiplying effect on the impact of HPCN on a wide range of business sectors.

All the work on applications and on basic software should follow adherence to existing standards or contribute to formulating new ones. The adherence to standard interfaces, development methods and programming languages will facilitate reusability of application software and system integration. It will also encourage transparency of the market

4. Recommended Actions

Different recommendations were discussed including topics for R&D and accompanying actions such as training and awareness. These types of actions could all be considered in the strategy of the focused cluster on HPCN.

4.1 Objectives

The proposed actions should aim at a number of objectives:

- accelerating the exploitation of HPCN in embedded applications in a wide range of industrial sectors.
- building confidence in the feasibility of projects requiring HPCN.
- ensuring a stable source of components and tools for the design of those systems.
- increasing the number of engineers experienced in the technology
- improving the transparency of the market

4.2 Actions

- **Application-oriented projects** should be started, to increase the experience and the number of practical examples of the industrial implementation of HPCN embedded systems. These project should be based on natural (supplier -)integrator - user chains. Each project should clearly identify the level of the value-added chain which it will address and demonstrate how this will lead to an improvement of the industrial position of the participants and of their customers.

In particular, a number of application projects should demonstrate innovation in the use of HPCN technology in spearheading and accelerating the application potential in new industrial sectors where the application challenges can be realistically met from a point of view of performance and cost with the available technologies and their predictable evolution.

These projects should build upon existing bases of standard technologies and tools, and help identify potential gaps in the offer. When needed, they could be linked with training activities for the personnel involved. Finally, they should participate in the promotion of a wider awareness and acceptance of HPCN technology.

- **Development of specific tools** must be promoted to respond to any gaps identified in the current offer of tools specific to the needs of embedded systems. Development of tools should be linked with the commitment of established software houses to bring these to the market. New tools may be needed to address the specification of large parallel real-time applications, fast prototyping, performance evaluation, debugging of real-time systems, proof of performance and reliability. Application system software libraries specific to the needs of embedded systems should be developed to form a basis for the development of embedded systems built on reusable software. These libraries should be scalable and portable.

- **Training measures** are proposed, aiming technical management (awareness) and system designers. Seminars for the technical management level would include management of concurrent engineering, assessment of intermediate results, and the advantages of using parallel processing in products (scalability, product life cycle). On the other hand, system designers would be trained to deal with complex applications requiring

HPCN, and to become familiar with the available design tools. The training of designers should be complemented by practical experience.

4.3. Organisation

A useful integration of the work in application-oriented projects and in tool-oriented projects could be produced by grouping such projects into clusters. Each cluster would include a number of application projects and rely on a group of suppliers for basic systems and design software, lead by well established software player(s) with a commitment to support and market project results. In the first phase of each application project, existing tools would be evaluated by engineers of the integrator companies to raise their experience on the corpus of available tools. This activity could be lead by tool providers and be performed at the premises of these. It could help identify missing features in the tools provided. Project clusters could also efficiently contribute in terms of training and awareness.