Northeastern University Research Institutes

Preproposal to Establish a Research Institute

on

Network and Pervasive Computing (NPC)

Submitted by

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PARTICIPATING NEU FACULTY

College of Engineering:

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College of Arts and Sciences:

J. Ayers (Biology), S. Reucroft, J. Swain (Physics)

Affiliated Academic Institutions:

California Institute of Technology, Carnegie Mellon University, University of Michigan Ann Arbor, University of Virginia, Fraunhof-Gesellschaft

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1 Abstract

Recent years have seen the widespread and unabated reliance of modern society on computing: according to International Data Corporation (IDC), in the year 2000 20 millions US households had multiple computers connected together at home as well as to the external world through different communication media (DSL, cable modems etc). By the year 2005, IDC predicts that half of all US households will fall in the category of connected multi-computer users. A similar trend has also occurred in the scientific community: the computational requirements for solving many grand-challenge problems (sub-atomic modeling for example) have evolved from a central super-computer facility to geographically distributed systems with a massive amount of communication and embedded resources.

These developments are based on a series of innovations that have fostered a new breed of technological modalities: the ubiquitous microcomputer chip of the 70's, the bulky personal computer (PC) of the 80's and the primitive laptop of the 90's have evolved into a pervasive environment which relies on a symbiotic arrangement of computation, storage, and communication to deliver a huge amount of information in a relatively short time to a large number of users. Pervasive computing gives us tools to manage information. As information is the new currency in the global economy, we increasingly rely on the electronic creation, storage, manipulation and transmittal of personal, industrial and scientific information with a high degree of reliability. In today's society, we require complete access of time-sensitive data regardless of physical location; so we expect *smart* devices - personal digital assistants, mobile phone, workstations and home entertainment systems - to access that information and work together in one seamless integrated system. Network and pervasive computing through wired and wireless communication will help us to manage information quickly, efficiently and effortlessly. This will enable people to accomplish an increasing number of transactions by providing convenient access to relevant information stored in powerful networks anywhere and anytime. The ultimate objective of these systems is to make life simpler by combining smart embedded devices into larger systems thus allowing a direct, simple and reliable access to both relevant information and services. Examples of pervasiveness in computing include wearable computers, residential gateways/portals, robots for industrial autonomous processing, web-based financial transactions and large-scale co-operative systems encountered for solving grand-challenge scientific problems.

The proposed Institute will focus on fundamental and experimental research issues revolving around *Network and Pervasive Computing* (NPC) to investigate the migration of computation by wired/wireless communication to a diverse set of applications in engineering and science (biology and physics). In particular, *integrated* (multi- and inter-disciplinary) techniques will be pursued to design, implement and test diverse computation/communication (C^2) prototypes and testbeds. Within this initiative we will be developing *advanced algorithmic processes* applicable to the two engineering domains of computation and communication: in the computational domain we are interested in building large-scale reliable computer networks by proposing and designing novel router and switching architectures. This will allow the implementation of effective procedures for routing, reconfiguration and scalability in computation. In the communication domain, we are interested in inter-level operability for massive wireless and mobile systems in fully and partially autonomous modes to allow full access to data and services. The solutions to these issues will permit the seamless integration of evolving hardware and software irrespective of their function in a large and cost-effective C^2 system. Our team will also develop *experimental prototypes and testbeds* by which pervasive applications such as biomimetic/neuroethologistic robots and particle physics can be implemented by C^2 systems using smart devices such as actuators, global positioning receivers, wireless radio terminals, and kinematic entities.

Our approach is both multi- and inter-disciplinary in nature. The linchpin of the NPC Institute is the *Laboratory for Integrated Research in Engineering and Science* (LIRES). LIRES will be the primary

experimental facility; its dual purpose is to provide the experimental infrastructure needed for state-of-the-art externally funded research projects and to have an on-campus showcase for Practice-Oriented-Education (POE) as focal element of an education at Northeastern University.

2 Lead Personnel

The following faculty members from different units at NEU are participating to the Research Institute;

Institute Director: Fabrizio Lombardi, International Test Conference Endowed Professor, ECE

Research Institute Faculty (10)

ECE Faculty: D. Avresky, S. Basagni, D. Brady, F. Kirchner, Y.B. Kim, B. McDonald and F.J. Meyer.

Biology Faculty: J. Ayers

Physics Faculty: S. Reucroft, J. Swain.

We have secured the participation of the following academic institutions as *outside collaborators*: Advanced Computer Architecture Laboratory (University of Michigan Ann Arbor), Dependable System Laboratory (Carnegie Mellon University), Center for Advanced Networking (Caltech), Center for Semicustom Integrated Systems (University of Virginia), Fraunhof-Gesellschaft (Germany).

3 Goals and Objectives

The *goal* of the proposed Institute is to establish a *unique* multi- and inter-disciplinary environment to conduct large-scale funded research in NPC with state-of-the-art experimental facilities for national and international prominence. The *unique features* of the proposed Research Institute are (a) the *integration* of science (physics and biology) and engineering practice into an integrated framework for exploring pervasive applications, (b) to support aggressive grantmanship and entreprenueral activities by the participating faculty; (c) the inclusion of extensive and rigorous experimental validation within an academic environment, (d) provision for on-campus demonstrations to support the POE and urban missions of NEU.

The *objective* of the NPC Institute is to position NEU at the unchartered yet fertile boundaries of computation and communication as applicable to many pervasive applications. The proposed Institute will be the focus organization by which the large industrial base of New England will be able to join in partnership with a national/international corsortium of academic institutions, each contributing to a topical area of NPC. This objective can be achieved at NEU for the following reasons. (a) Faculty interest and productivity in NPC related areas have grown considerably over the last few years. (b) We have some pockets of excellence which span across units (in ECE and Biology, the biomimetic robotics as an example) whose proven (past and present) success in funding can be dramatically enhanced by enlarging the scope of investigation to multi-disciplinary research. (c) The co-operative experience of our undergraduates matches very well the experimental nature of the Institute and opens the concrete possibility to have industry sponsors for undergraduate research.

The NPC Institute will also have a significant *educational role*: we expect to participate in innovative graduate and undergraduate initiatives (such as the MS in Telecommunication and Quantum Engineering) by introducing new offerings as well as laboratory courses. These will complement our research mission and provide an *additional stream* of revenue to sustain the experimental state-of-the-art facilities in LIRES. Furthermore we will be actively involved in the School Cosmic Ray Outreach Program (SCROD) to merge leading edge cosmic ray research with education and outreach by deploying cosmic ray detectors to few high Schools in Boston. LIRES will integrate this service within its technical scope by providing a new prototype for the electronics in the front-end detector.

4 Technical Milestones

The NPC Institute will build on existing faculty expertise and laboratories to dramatically expand our current activities and resources. In the past two years the ECE Department has undergone a significant expansion of its experimental facilities: more than 400,000 dollars of C^2 equipment has been acquired/purchased from various companies (Agilent, Cisco, Marconi and Compaq) using externally procured funds to support educational and research in the Wireless Lab, the RF-Wave Lab, the Network Communication Lab and the Network Computing Lab. These entities are currently disjoint; as part of the NPC Institute, they will be *functionally coordinated* using LIRES. LIRES will be supported by leading companies as predicated on establishing the Institute. The novelty and success of the NPC Institute are based on the *substantial departure* from current practice of limited experimentation in single PI awards. LIRES will be designed to support modularity and versatility in experimental facilities for a wide range of pursuits. As representative of our research accomplishments, testbeds involving prototyping will be implemented; a list would include but not limited to:

(a) *Intensive Computation:* this testbed will evolve from the current Network Computing Laboratory in the ECE Department. It will utilize the latest gigabit technology (ServerNet II) from Compaq Computers for cluster design. The Compact Muon Solenoid experiment planned at CERN will be used as pervasive application to reconstruct and simulate data from a remote site (Switzerland) on proton-proton collisions using a configurable networked cluster of workstations. This will allow us to show the inherent advantages of newly developed high-speed server and network technologies to solve pervasive tasks with intensive computation in the physical sciences. This testbed will also confirm the viability of network computing to handle a large volume of data distributed over wired/wireless media (i.e. the web) in a scalable and dependable manner.

(b)*Biomimetic Robotics:* this testbed stems from the on-going robot prototypes in the biology (the "lobster") and ECE (the "scorpion") departments to show the capability of C^2 systems to handle real-time processing for industrial applications. In this testbed we will implement a full system (hardware and software) on an ad-hoc network to coordinate a team of robots working on a common task. Wireless communication and associated protocol entities will be used to deliver information to/from the wired and custom computational infrastructure for manipulation and processing (for example decision and control based on partial images). We may include an exploratory controller based on artificial silicon neuron design for autonomous behavior as additional modality in our testbed.

(c) *Computation/Communication Interoperability:* this testbed will address fundamental issues for designing systems for next-generation interoperability of C^2 services and media. This testbed will utilize a combination of open-source technology (such as hand-held computers with radio cards) and smart devices (such as optical display glasses by MicroOptical Corporation) together with InfiniBand servers to provide a comprehensive solution for a wide class of systems ranging from utility residential gateways to extensive web-based facilities. We are particularly interested in demonstrating the C^2 viability in improvements to the communication protocol stack (TCP/IP) as well as computational scalability with uninterruptable service.

5 External Participation, Funding and Professional Activities.

The external participation by industrial and academic affiliates is expected to play a significant role in advising on current and future technology developments as well as procuring additional research funding. The current sponsors of the NEU faculty participants are (in some cases multiple awards are applicable to a single sponsor):

Industrial Sponsors: LTX, United Technology Research Center, Wood Hole Oceanographic Institute, Pinpoint Corporation, Compaq Computers, Tandem Research Laboratories, Samsung Advanced Research Institute, Lucent, Seodu Logic Corporation, SRC.

Federal Sponsors: NSF, DARPA, ONR

Research expenditures at NEU for the above sponsored projects exceeded the one million dollar mark in AY00-01. As multi-disciplinary experimental research is the recipient of the largest portion of federal and industrial funding, we will be targeting initiatives which allow us to successfully respond to broad based funding announcements (such as the BAA on the Multi-University Research Initiative by DoD and the Experimental/Research Infrastructure Grants by NSF). This will be in *addition* to an extensive list of single PI awards already in place. Participant faculty members have already a close working relationship with our external collaborators (as listed in a previous section), so we expect this relationship to be further strengthen by the NEU commitment to establish the NPC Institute.

In parallel with funding, we will continue the current involvement of *hosting* prestigious meetings (conferences and symposia) sponsored by professional societies in the Greater Boston area. We have already proceeding in 2002 and 2003 a the main host for the two IEEE sponsored international symposia on Network Computing and VLSI Design. We expect to *complement* this activity with a series of IEEE sponsored workshops to attract practitioners from industry on the Northeastern campus as well as enabling faculty to be involved in guest editorships of Special Issues in archival journals (such as IEEE TC, IEEE Micro, IEEE TPDS, and ACM/Kluwer Journal on Special Topics in Mobile Networking and Applications).

6 Stages of Development for Self Sufficiency

The operation of the NPC Institute will be managed upon a *three-stage development plan*:

(1) Upon approval from NEU for the NPC Institute the highest priority will be to establish LIRES; resources will be allocated for the *purchase of equipment* and support of *research assistantships*. The research assistantships will be directed to the implementation of the testbeds and their integration within LIRES. Simultaneously, we will invest resources to foster synergy among participating faculty to spur fundamental research activities. Within this stage we foreseen a significant increase in industrial support for the development of LIRES and possibly few grant awards to small team of participating faculty and associated academic institutions (in addition to single PI awards). We project this initial phase to span the first two years of existence.

(2) The intermediate stage (18 month duration) will focus on pursuing significant external support for experimental research. Within this stage, our faculty will *transition* from individual funding efforts to a significant participation in proposals of substantial level (multi-million dollars). We will aggressively apply to DoD programs (mainly Darpa) and NSF infrastructure-type of grants (IGERT and MRI) and strengthen our relation with international and industrial partners. LIRES will be supported from a significant portion of external support. This stage will start to propel the NPC Institute on a level of international prominence as our technical accomplishments substantiated by a rigorous experimentation will start to be recognized by the technical community at large.

(3) The third stage will encompass the *long-term viability* of the NPC Institute mainly in terms of fiscal sufficiency. By the end of the last stage (of 18 month duration) the Institute should have in place both long-term and short-term funding to pursue an upgrade and expansion of LIRES. We will also focus on graduating a substantial number of doctorial students to foster continued collaboration with their employers (academic and industrial).

Note that after the initial phase, we will allocate the internal resources provided by NEU to us on a *competitive basis*, hence providing incentive to support faculty research accomplishments.