PDF - EMBEDDED EVERY-WHERE: A RESEARCH AGENDA FOR NETWORKED SYSTEMS OF EMBEDDED COMPUTERS - researchcub.infoions and models fordevelopers. companies. Expanding access to this data by more researchers is animportant role for a government agency. The committee believes that NIST alsohas a particularly critical role to play in this realm as the agency thatestablishes confidence in information systems. NIST is seen as an outsideobserver that can provide objective services and analysis. It has an importantrole in the standardsdevelopment process, allowing the work done in industry tobe illuminated in a fair and open fashion. As this report has emphasized,interoperability for EmNets will be very important, and standards will beneeded for such interoperability. Given that many of the standards in this arenaare likely to arrive as de facto rather than de jure standards, NIST canprovide an objective analysis of them and reduce barriers to entry withreference implementations of the technology itself and/or referenceimplementations of conformance testing tools. More specifically, NIST, throughactivities such as its Aroma Project,17 which focuses on testing, 17For moreinformation, see <http://www.nist.gov/aroma/>. Embedded, Everywhere: AResearch Agenda for Networked Systems of Embedded Computers Copyright NationalAcademy of Sciences. All rights reserved. CONCLUSIONS AND RECOMMENDATIONS 199measuring, and standardizing pervasive computing technology, should play asignificant role in the two areas as EmNets become ever more widespread.Recommendation 3. The National Institute of Standards and Technology shoulddevelop and provide reference implementations in order to promote openstandards for interconnectivity architectures. It will be important to promoteopen standards in the area and promote system development using commercialcomponents by making public domain device drivers available. Recommendation 4.The National Institute of Standards and Technology should develop methodologiesfor testing and simulating EmNets in light of the diverse and dynamic conditionsof deployment. Comprehensive simulation models and testing methodologies forEmNets will be necessary to ensure interoperable, reliable, and predictablesystems. In particular, the development of methodologies for testingspecification and interoperability conformance will be useful. In the processof these endeavors, NIST can play a key role in data collection anddissemination of EmNet-related information for use by the larger research anddevelopment community. Recommendations to the National Science Foundation TheNational Science Foundation (NSF) has a strong track record in promotingmultidisciplinary research and integrated research and education programs. Morerecently, it has been increasing its support for integrated systemsprojects—for example, the Information Technology Research (ITR) program. Allthree areas—multidisciplinary research, integration of research and education,and integrated systems approaches— will be of great importance in the supportof EmNet-related research projects, and all of them—in particular,systems-oriented work—should be aggressively pursued and includecross-divisional efforts where necessary. Specific recommendations for NSF arebelow. Recommendation 5. The National Science Foundation should continue toexpand mechanisms for encouraging systems-oriented, multi-investigator,collaborative, multidisciplinary research on EmNets. NSF is funding work inseveral areas related to

EmNets (see Box 6.6). Much of this work continues tobe done by a single principal investigator (and graduate students) operating ona small budget. As noted in this Embedded, Everywhere: A Research Agenda forNetworked Systems of Embedded Computers Copyright National Academy of Sciences.All rights reserved. 200 EMBEDDED, EVERYWHERE BOX 6.6 A Sampling of theNational Science Foundation's EmNet-related programs Scalable InformationInfrastructure and Pervasive Computing NSF is supporting work in scalability,security, privacy, sensors and sensor networks, and tetherfree networking andcommunications in this program. Its goal is to advance the technicalinfrastructure to support human-to-human, human-tocomputer, andcomputer-to-computer remote communication. Wireless Information Technology andNetworks This program funds research to provide a foundation for designinghighinformation-capacity wireless communication systems for full mobility. Suchdesign will require synergistic, multidisciplinary research effortsencompassing a breadth of communications functions from the physical throughapplication layers. Electronics, Photonics, and Device Technologies Thisprogram funds research in the areas of microand nanoscale devices, components,and materials, advanced methods of design, modeling, and simulation of suchdevices and components, and improved techniques for processing, fabrication,and manufacturing. report, research on EmNets will require that such singleinvestigator research be complemented by collaborative experimental researchthat brings together researchers from different disciplines to focus on acommon problem. Had this report been written several years ago, it would haverecommended that NSF move toward larger-scale, experimentally driven,risk-taking research. NSF's ITR program appears to be doing just that. ITR alsoreinforces attention to the social and economic dimensions of informationsystems. This program, or others like it, could serve as a useful vehicle forpursuing some of the topics pinpointed in this report. The key to achievingsuccessful multidisciplinary research is not just a matter of funding levels. Aflexible process is required that can incorporate perspectives from a broadrange of relevant disciplines. Recommendation 6. The National ScienceFoundation should develop programs that support graduate and undergraduate multidisciplinaryeducational programs. Embedded, Everywhere: A Research Agenda for NetworkedSystems of Embedded Computers Copyright National Academy of Sciences. Allrights reserved. CONCLUSIONS AND RECOMMENDATIONS 201 With respect to education(see Box 6.1), NSF could take the lead in tackling institutional barriers tointerdisciplinary and broad systemsbased work. NSF has a history of encouraginginterdisciplinary programs and could provide venues for such work to beexplored (as is being done in the ITR programs) as well as foster and fundjoint graduate programs or joint curriculum endeavors. One way to do this wouldbe to provide incentives to programs that successfully cross disciplinaryboundaries. For example, faculty working on interdisciplinary research oftenhave difficulty securing institutional support for work deemed outside thescope of their home department. A program that removed this drawback byproviding funding for such work could stimulate interdisciplinary research andcourse material in colleges and universities. Another way would be to expandthe Graduate Fellowship Program to support more interdisciplinary proposals.Suitable evaluations of

proposals would be needed to implement thisrecommendation. Recommendations to Other Federal Agencies The NationalAeronautics and Space Administration (NASA) and the Department of Energy (DOE)were two of the earliest innovators and adopters of EmNets. While NASA and DOEapplication domains can be quite specialized, two things are clear: The computerscience community would benefit from hearing of and seeing this earlier (andcontemporary) work, and NASA and DOE themselves would benefit from the moregeneral pursuit of this technology by the broader computer science community.Both agencies have long histories in systems engineering as well as in computerscience and so could serve as a useful bridge between various communities,especially regarding the development of EmNets. NASA, for example, has a stronginterest in safety and reliability, and DOE has long been involved inreliability issues. Their expertise, when applicable, could be shared withothers in related research areas; in addition, the two agencies would benefitfrom the generalizations that the broader research community could provide.More explicit cooperation and communication would be beneficial to everyone andwould greatly advance the field. The agencies with needs for EmNets shouldtogether promote expanded experimental research with a shared, experimentalsystems infrastructure. The committee expects that coordination needs could besupported by the various organizations and groups associated with federalinformation technology research and development.18 Open-platform sys18TheNational Coordination Office for Information Technology Research andDevelopment and related groups can facilitate cross-agency coordination, forexample. Embedded, Everywhere: A Research Agenda for Networked Systems ofEmbedded Computers tems of various scales, low-power components and thesoftware drivers for these components, debugging techniques and software,traffic generators—all can be shared across research programs when applicable,avoiding inefficient redundancy in those parts of the system where there ismore certainty. The research communities should combine their efforts increating enabling components, such as a range of MEMS-based sensors andactuators that are packaged in such a way as to be easily integrated intoexperimental EmNet systems.

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