NSF/Intel Partnership on Information-Centric Networking in Wireless Edge Networks (ICN-WEN)

PROGRAM SOLICITATION
NSF 16-586

National Science Foundation

Directorate for Computer & Information Science & Engineering
Division of Computer and Network Systems

Intel Labs University Collaboration Office

Letter of Intent Due Date(s) ***(required)*** (due by 5 p.m. submitter's local time):

September 20, 2016

Full Proposal Deadline(s) (due by 5 p.m. submitter's local time):

November 21, 2016

IMPORTANT INFORMATION AND REVISION NOTES

Due to repairs to the Foundation's electrical systems, there will be no access to FastLane, Research.gov or the NSF website on September 17-18, 2016. The deadline date for Letters of Intent for this solicitation has therefore been changed to September 20, 2016 at 5:00 PM submitter's local time.

This joint solicitation from NSF and Intel seeks proposals to be considered for both NSF continuing or standard grants and Intel agreements (i.e., contracts, grants or gifts). Intel agreements contain provisions for possible direct, on-site participation in research by Intel researchers-in-residence (RinRs).

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) (NSF 16-1), which is effective for proposals submitted, or due, on or after January 25, 2016.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

NSF/Intel Partnership on Information-Centric Networking in Wireless Edge Networks (ICN-WEN)

Synopsis of Program:

Next-generation wireless networks, utilizing a wide swath of wireless spectrum and an array of novel technologies in the wired and wireless domains, are on the cusp of unleashing a broadband revolution with promised peak bit rates of tens of gigabits per second and latencies of less than a millisecond. Such innovations will make possible a new set of applications such as autonomous vehicles, industrial robotics, tactile Internet applications, virtual and augmented reality, and dense Internet of Things (IoT) deployments. A key requirement of these applications is fast ***information response time*** that is invariant as a function of the bandwidth demanded, users/devices supported, and data generated, of which low-latency wireless access time is only one component. Intrinsic security, seamless mobility, scalable content caching, and discovery/distribution services are also essential for such applications.

This solicitation seeks unique data network architectures featuring an ***information plane*** *using an Information-Centric Networking (ICN) approach* and addressing discovery, movement, delivery, management, and protection of information within a network, along with the abstraction of an underlying ***communication plane*** creating opportunities for new efficiencies and optimizations across communications technologies that could also address latency and scale requirements.

Cognizant Program Officer(s):

Please note that the following information is current at the time of publishing. See program website for any updates to the points of contact.

- Thyagarajan Nandagopal, Program Director, NSF CISE/CNS, telephone: (703) 292-8950, email: tnandago@nsf.gov

- Darleen L. Fisher, Program Director, NSF CISE/CNS, telephone: (703) 292-8950, email: dlfisher@nsf.gov
- David Corman, Program Director, NSF CISE/CNS, telephone: (703) 292-8950, email: dcorman@nsf.gov
- Jeff Foerster, Director, Emerging Connectivity Systems Research, Intel Labs, telephone: (503) 264-6859, email: jeffrey.r.foerster@intel.com
- David Ott, Program Director, Intel Labs, telephone: (480) 554-7868, email: david.e.ott@intel.com

Applicable Catalog of Federal Domestic Assistance (CFDA) Number(s):

- 47.070 --- Computer and Information Science and Engineering

Award Information

Anticipated Type of Award: Standard Grant or Continuing Grant or Intel Agreement (i.e., Contract, Grant or Gift)

Estimated Number of Awards: 2 to 3

Approximately 2 - 3 awards are anticipated, each up to $3,000,000 total and of 3 years in duration, subject to the availability of funds and quality of proposals received.

Anticipated Funding Amount: $6,000,000

subject to the availability of funds and quality of proposals received.

Eligibility Information

Who May Submit Proposals:

Proposals may only be submitted by the following:

- Universities and Colleges - Universities and two- and four-year colleges (including community colleges) accredited in, and having a campus located in, the US acting on behalf of their faculty members. Such organizations also are referred to as academic institutions.

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

Limit on Number of Proposals per PI or Co-PI: 1

An individual may participate as PI, co-PI, or senior personnel in **no more than one proposal** submitted in response to this solicitation. In the event that an individual exceeds this limit, the first proposal received within the limits will be accepted based on the earliest date and time of proposal submission (i.e., the first proposal received will be accepted and the remainder will be returned without review). **No exceptions will be made.**

This limit on the number of proposals per PI, co-PI, or senior personnel applies only to this NSF/Intel Partnership on Information-Centric Networking in Wireless Edge Networks program solicitation.

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

- **Letters of Intent:** Submission of Letters of Intent is required. Please see the full text of this solicitation for further information.
- **Preliminary Proposal Submission:** Not required
- **Full Proposals:**
  - Full Proposals submitted via FastLane: NSF Proposal and Award Policies and Procedures Guide, Part I: Grant Proposal Guide (GPG) Guidelines apply. The complete text of the GPG is available electronically on the NSF website at: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg.
  - Full Proposals submitted via Grants.gov: NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov Guidelines apply (Note: The NSF Grants.gov Application Guide is available on the Grants.gov website and on the NSF website at: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide)

B. Budgetary Information

- **Cost Sharing Requirements:**

  Inclusion of voluntary committed cost sharing is prohibited.

- **Indirect Cost (F&A) Limitations:**

  Not Applicable

- **Other Budgetary Limitations:**

Not Applicable

C. Due Dates

- **Letter of Intent Due Date(s)** ***(required)*** (due by 5 p.m. submitter's local time):

  September 20, 2016

- **Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):

  November 21, 2016

Proposal Review Information Criteria

Merit Review Criteria:

National Science Board approved criteria. Additional merit review considerations apply. Please see the full text of this solicitation for further information.

Award Administration Information

Award Conditions:

Additional award conditions apply. Please see the full text of this solicitation for further information.

Reporting Requirements:

Additional reporting requirements apply. Please see the full text of this solicitation for further information.

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I. INTRODUCTION

Next-generation wireless networks—utilizing a wide swath of wireless spectrum and an array of technologies such as network densification, Multiple Input Multiple Output (MIMO), Device-to-Device (D2D) communications, Cognitive Radios (CR), integration of heterogeneous radio technologies, Software Defined Networks (SDN), and Network Function Virtualization (NFV)—are on the cusp of unleashing a broadband revolution with promised peak bit rates of tens of gigabits per second and latencies of less than a millisecond. Such innovations will make possible a new set of applications that we refer to here as "**beyond 5G" (B5G) applications** defined as applications whose latency and/or scalability characteristics require the capabilities and performance of emergent 5G wireless networks enhanced with additional technologies. Examples of such applications include autonomous vehicles, industrial robotics, tactile Internet applications, virtual and augmented reality, as well as massive and/or dense Internet of Things (IoT) deployments.

A key requirement of these applications is fast ***information response time*** that is invariant as a function of the bandwidth demanded, users/devices supported, and data generated. While low-latency wireless communication will be a feature of emerging 5G radio networks, it is only one component of the total information response time requirement, which also considers the availability,

placement, and real-time management of data. Therefore, the design space of wireless networks must go beyond 5G wireless networks in order to address information flow performance to support such applications. Concurrently with development of new wireless technologies, information-centric network architectures are also being explored; they promise intrinsic security, scalable content caching, discovery and distribution services, seamless mobility, and potential time-saving features.

An ideal data network architecture in the B5G application context creates an ***information plane*** that directly addresses discovery, movement, delivery, and management of information within a network, while the abstraction of the underlying ***communication plane*** creates opportunities for new efficiencies and optimizations across communication technologies towards also addressing latency and scale requirements. The information plane also treats information protection as a first-order consideration within the network infrastructure that supports it. While legacy network deployments make testing a clean-slate global architecture challenging, the wireless edge-based nature of the B5G applications provides an opportunity to overcome these challenges by deploying 'clean-slate' approaches as self-contained information 'islands'. Such islands can be deployed at the network edge with a translation gateway to connect the 'clean-slate island' to the rest of the Internet and other legacy networks. An Information-Centric Networking (ICN) approach, aimed at moving information within the desired information response times rather than just routing bits or connecting end points, generalizes network design principles in this island. ***The goal of this solicitation is to identify a suitable co-design of Information-Centric Networks and future wireless networks to support B5G applications in this edge island.***

In ICN-wireless islands at network edges, collections of IoT wireless devices (e.g., vehicles, cameras, drones, robots, sensors) may have high data rate sensors (e.g., multiple 4K cameras in an autonomous vehicle or drone) and/or massive numbers of devices (e.g., fields of sensors) collecting data for a specified purpose within a designated physical region. Within the island, an information-centric infrastructure labels, stores, retrieves and routes information among the devices, data repositories, and local compute and analytics systems. By 'information', we mean here data collected and/or used as well as objects that contain sets of data that could include location of devices collecting/using data, etc. The ICN infrastructure may also provide mobility services. Wireless infrastructure components include the wireless access points (we include base stations when we use the term 'access point'), spectrum available for use, antenna systems, and connectivity of the wireless access points locally within the island. *Management of these components should also subscribe to the Information-Centric Networking model*. This may include location of radio infrastructure elements, radio frequencies, feature capabilities, network slice configurations, etc. The island also includes additional elements such as data analytics to assess and optimize tracking of mobile devices, and computing elements that filter, process, compress, encrypt, etc., to more effectively and efficiently serve information flow and response times on the information plane within the island.

This solicitation, therefore, seeks to develop clean-slate information-centric architectures, deployable as islands at the network edge, to (i) improve information response time for B5G applications; (ii) scale to support device density and aggregate data volume; and (iii) address information protection.

II. PROGRAM DESCRIPTION

This program targets wireless networks to support applications whose latency and/or scalability requirements will necessitate capabilities beyond those supported by emergent 5G wireless networks. Two B5G application areas of particular interest that the proposals responsive to this program solicitation should address are :

- ***Ultra low-latency applications.*** Applications in this area often include real-time control loops that are highly sensitive to delay, and this program is especially interested in *tactile Internet* applications that demand extremely low latency as well as high availability, reliability, and security.[1] Tactile Internet applications (e.g., robotics, telepresence, virtual and augmented reality, industrial control systems, healthcare) focus on end-to-end latency on the order of human tactile or haptic response time, or approximately 1 millisecond (ms). End-to-end latency includes transmission time to and from a control server, and the information processing time in between.
- ***Massive IoT deployments***. Such applications explore the limits of scalability in terms of numbers of devices, and the aggregate volume of data to be transmitted by participating devices. This program is especially interested in ***large-scale sensor networks*** that might be found in smart buildings, agriculture, or environmental monitoring contexts. Smart services will become pervasive in urban areas, and usage will also grow in suburban and rural areas. Illustrative applications include metering (e.g., gas, energy, and water); city or building light management; pollution/temperature/humidity/noise monitoring; and vehicle traffic control. The aggregation of all these services leads to a very high density of devices, and a wide range of operational characteristics, all sharing a common communication infrastructure and interworking framework.[2]

Summarizing the overall program objective, researchers are asked to respond to the following broad challenge: ***Investigate and prototype architectures, protocols, and/or technologies based on the application of ICN to an 'island' wireless edge network, and demonstrate (quantifiably) the effectiveness in addressing the challenges of B5G applications as compared to non-ICN approaches.***

Researchers should keep in mind the following points:

- ***ICN islands at network edges.*** Researchers should focus on ICN islands at the wireless network edges. There is no need or desire to extend the model used within the island in order to apply it to the global Internet. Do not assume the global Internet is ICN-enabled, or that it will be ICN-enabled in the future.
- ***Clean slate.*** Researchers are at liberty to consider clean-slate approaches within the island and should not feel limited by backward capability requirements for networking.
- ***Realistic deployment model.*** Researchers should consider how their scheme could be implemented, and whether it could leverage existing technologies and/or standards while providing innovative features and functionality.

In responding to the above challenge, *researchers are asked to address the following three problem dimensions*, each of which represents an essential component in a complete solution architecture. Sample research issues are given for each dimension, but are intended to be illustrative and not exhaustive or prescriptive. Proposals submitted in response to this solicitation are expected to address all three dimensions in a well-integrated manner. Researchers are welcome and encouraged to explore additional issues lying outside these identified dimensions as long as the required dimensions are adequately addressed within the research agenda.

Dimension 1: ICN-enabled Wireless Device Endpoints. Researchers are asked to consider the design implications of ICN for B5G wireless devices. Researchers should demonstrate the advantages and benefits that ICN could bring to deployment and management of wireless device platforms and the B5G applications running on them within the island. Note that devices will interact with the broader network architecture within the island, so this research vector may include a discussion of other devices, communication protocols, infrastructure elements, and so on. That is, devices need not be treated in strict isolation. The idea is to focus on device issues and components within the broader network architecture of the edge network island.

Sample research issues may include (but are not limited to):

- *Integration of ICN within the wireless protocol stack.* Research considers where ICN should be placed, and the benefits and tradeoffs to various alternatives.
- *Wireless communication optimizations leveraging ICN.* Research looks at wireless optimizations that are made possible by coupling device communications with ICN.
- *Device power efficiency.* Research considers the use of ICN to improve device power efficiency compared to existing wireless network paradigms, e.g., managing device enrollment and/or presence in the network with minimal device activity required.
- *Mobility.* Research considers the use of ICN to help with device mobility challenges within wireless networks (e.g., zero-loss handovers between access points).
- *Device management.* Research considers how ICN-wireless devices are deployed and configured. This includes ICN approaches to identifying, tracking, discovering, and managing devices.
- *Addressing wireless heterogeneity.* Research looks at how ICN can be used to support a diverse, heterogeneous set of radio access technologies, spectrum types, and network topologies.
- *Device-to-device communications.* Research considers how ICN might be used to facilitate D2D communications, including one-to-many and many-to-one group communications.
- *Programming interfaces.* Research looks at application programming interface design and what features should be supported for B5G applications.

Dimension 2: ICN-Wireless Network Infrastructure and Architectures. Researchers are asked to consider the design implications of ICN for wireless network architectures that support the challenging B5G applications of the future. Work should consider how ICN can be integrated into the wireless edge network infrastructure and the benefits and disadvantages of coupling ICN and the wireless network infrastructure.

Sample research issues may include (but are not limited to):

- *Wireless communication optimizations leveraging ICN.* Research develops and demonstrates wireless communication optimizations based on the introduction of ICN.
- *ICN optimizations leveraging wireless communications.* Research develops and demonstrates information plane optimizations that are made possible by an underlying wireless communications architecture.
- *Information latency.* Research examines schemes for reducing information latency. Work quantifies potential benefits, identifies best/worst case scenarios, and clarifies underlying dynamics.
- *Device and data scaling.* Research examines schemes for using ICN to address the scalability of wireless networks. Work includes both data volume and number of devices as key scaling parameters.
- *Infrastructure programmability and re-programmability.* Research considers how an ICN-managed edge network architecture may be implemented and re-configured through use of programming tools.
- *Wireless communication analytics.* Research looks at the use of ICN to enable collection and exchange of wireless communication analytics in various contexts over time and space (e.g., interference management).
- *Wireless distributed computation.* Research investigates use of ICN to distribute and manage computation within and across island wireless edge networks.
- *Network management.* Research looks at applying ICN principles and methodologies to the management of wireless transmit/receive point (TRP) infrastructure, both stationary and mobile.
- *Reliability.* Research considers how the architecture enables a high level of information plane reliability for B5G applications.

Dimension 3: Security and Privacy. Researchers are asked to understand the security and privacy aspects of applying ICN to a wireless edge network. Subareas of importance include:

- Securing the ICN information plane in the context of wireless networks and mobility;
- Using ICN to secure wireless network operations and management; and
- Addressing the security of new ICN-wireless co-design features, resource management techniques, distributed computation approaches, and cross-layer interactions.

Researchers should consider how ICN could provide benefits to the security and privacy of wireless network architectures and associated communication protocols. Work could further focus on how to protect network management operations by leveraging ICN principles in the wireless communication architecture. Work should also help to understand attack surfaces, threats, and security requirements more generally. The architecture and application of key management, identity management, authentication/authorization protocols, etc., supporting the effective use of cryptography is of primary interest.

Sample research issues may include (but are not limited to):

- *ICN information plane security.* Research examines how the ICN information plane and associated protocols can be made robust against attacks. This includes security considerations that follow from the same wireless infrastructure within an island being shared by multiple B5G applications.
- *Network operations and management.* Research examines how the ICN information plane may be used to effectively secure wireless network operation and management, including validation and policy enforcement (e.g., managing network topology as devices and data flows join and leave).
- *Device and data security.* Research considers design aspects of wireless device and data security. This includes an understanding of attack types and new security defenses made possible by ICN use.
- *Security and privacy life cycle.* Research shows how security can be designed into the ICN wireless architecture in a sustainable manner that supports updates, technology end-of-life, and new algorithms/protocols.
- *Security configuration and management.* Research shows where and how security management can be performed within the architecture (e.g., access control changes).
- *Policy-driven infrastructure.* Research demonstrates how security and privacy policy can be embedded in and managed by the ICN information plane itself. This work includes an understanding of the issues relating to policy-enhanced architectures.
- *Attack detection.* Research shows how ICN can be used to detect and respond to attacks within the context of the wireless network island. Additionally, research may demonstrate forensics approaches.

Validation

It is expected that research proposals will include a strong prototyping component. In addition to proof-of-concept, prototypes help to quantify approach benefits and effectiveness, and to better understand implementation and deployment challenges within more realistic contexts.

Proposed architectures, protocols, and/or technologies can be implemented using whatever wireless test infrastructure might be available to researchers. It is understood that academic researchers may not have access to testbed infrastructures on the level of

production networks. As is widely practiced in academic wireless research, key tenets of an architecture can be explored through the judicious use of simulators, emulation environments, and real-world test infrastructure as available. Researchers are strongly encouraged to make use of existing large-scale experimental network infrastructures intended for research, including, for example:

- GENI, or Global Environment for Network Innovations (www.geni.net); and
- PlanetLab (www.planet-lab.org).

To test the effectiveness of a given approach to ICN and wireless, researchers should address requirements from both B5G application areas described at the beginning of this section (ultra-low latency applications and massive IoT deployments). At least one major B5G application must be featured, although support for two distinct and realistic applications is highly desirable. We note, however, that the focus here is to exercise the wireless networking capabilities for information flows and not to showcase complex application implementations. If at all possible, researchers are encouraged to make use of applications already implemented within the academic or open source community, and to avoid lengthy implementations of their own. Realistic case studies are appreciated for their authentic requirements, device behavior, and traffic characteristics. It is expected that researchers will need to adapt applications for the purpose of ICN-wireless infrastructure test and validation.

Researchers are asked to consider evaluation metrics on at least two levels. First, *quantitative performance metrics* should be used to establish the benefits of a proposed scheme in the context of wireless network and device research. For example, researchers might consider network (or information) latency, measures of reliability, device power efficiency, architecture scalability in terms of data volume and/or number of devices, peak and average throughput, and so on. Such metrics enable comparisons with non-ICN wireless alternatives to understand the gains offered by a particular ICN-based approach.

Second, researchers may consider metrics that address *qualitative benefits* to their approach not easily measured by quantitative performance metrics. Some illustrations include programmability, flexibility of application, ease of management, usability when applied at scale, robustness against attacks or failures, extensibility, composability, and so on.

In developing test environments, researchers should be aware of 3GPP's (3^{rd} Generation Partnership Project) expectations for future 5G networks.[3] Some performance indicators currently under discussion are listed below:

- *Peak data rates:* 20 Gbps DL (downlink), 10 Gbps UL (uplink) per sector;
- *Control plane latency - time from battery-efficient IDLE state to ACTIVE data transfer:* 10 ms;
- *User plane latency - time to successfully deliver an application layer data packet:* 0.5 ms DL, 0.5 ms UL for URLLC (Ultra Reliable Low Latency Communications); and 4 ms DL, 4 ms UL for eMBB (Enhanced Mobile Broadband);
- *Reliability - probability of successfully transmitting within 1 ms:* 99.999% ($1-10^{-5}$); for some applications (e.g., remote surgery), 99.999% at a data rate of 300 megabits per second (Mbps);
- *Connection density - total number of devices fulfilling defined quality of service (QoS) per unit area:* 1 million devices/km^2; and
- *Mobility targets – maximum user speed at which defined QoS can be achieved:* 500 km/hr (e.g., high speed trains).

As far as possible, prototypes should address 5G expectations of future networks rather than today's wireless performance levels and standards.

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[1] *ITU-T Technology Watch Report, The Tactile Internet.* International Telecommunication Union. August 2014.

[2] *NGMN 5G White Paper v1.0.* Next Generation Mobile Networks (NGMN) Alliance. March 2015.

[3] *3GPP TR 38.913, Technical Specification Group Radio Access Network: Study on Scenarios and Requirements for Next Generation Access Technologies (Release 14). March 2016.*

III. AWARD INFORMATION

Anticipated Type of Award: Continuing Grant or Standard Grant or Intel Agreement (i.e., Contract, Grant or Gift)

Estimated Number of Awards: 2 to 3

Approximately 2 - 3 awards are anticipated, each up to $3,000,000 total and of 3 years in duration, subject to the availability of funds and quality of proposals received.

Anticipated Funding Amount: $6,000,000

Estimated program budget, number of awards, and average award size/duration are subject to the availability of funds and quality of proposals received.

IV. ELIGIBILITY INFORMATION

Who May Submit Proposals:

Proposals may only be submitted by the following:

- Universities and Colleges - Universities and two- and four-year colleges (including community colleges) accredited in, and having a campus located in, the US acting on behalf of their faculty members. Such organizations also are referred to as academic institutions.

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

Limit on Number of Proposals per PI or Co-PI: 1

An individual may participate as PI, co-PI, or senior personnel in **no more than one proposal** submitted in response to this solicitation. In the event that an individual exceeds this limit, the first proposal received within the limits will be accepted based on the earliest date and time of proposal submission (i.e., the first proposal received will be accepted and the remainder will be returned without review). **No exceptions will be made.**

This limit on the number of proposals per PI, co-PI, or senior personnel applies only to this NSF/Intel Partnership on Information-Centric Networking in Wireless Edge Networks program solicitation.

Additional Eligibility Info:

Subawardees may include universities and two-and four-year colleges (including community colleges) accredited in, and having a campus located in, the US acting on behalf of their faculty members; and non-profit, non-academic organizations such as independent museums, observatories, research laboratories, professional societies and similar organizations located in the US that are directly associated with educational or research activities in the computing and information sciences (and closely related fields).

V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

A. Proposal Preparation Instructions

Letters of Intent *(required)*:

All Letters of Intent (LOI) must be submitted by the proposing organization's Sponsored Projects Office via FastLane (http://www.fastlane.nsf.gov/fastlane.jsp). For collaborative projects, the Lead Institution must submit one LOI on behalf of the entire project representing all collaborating institutions involved in that project.

Format:

The LOI must address the following (there should be no attachments or supplemental documents) in a maximum of 2 pages [use the "Synopsis" and "Other Comments" boxes (each with a 2,500 character limit) to provide this information].

- Project synopsis;
- How the project addresses the three dimensions sought in the solicitation; and
- Proposed project team composition and expertise.

Proposers are permitted to change the project focus and team composition in the full proposal, departing from the content in the LOI. However, the lead institution must remain the same in the Full Proposal as in the LOI.

Letter of Intent Preparation Instructions:

When submitting a Letter of Intent through FastLane in response to this Program Solicitation please note the conditions outlined below:

- Submission by an Authorized Organizational Representative (AOR) is required when submitting Letters of Intent.
- A Minimum of 0 and Maximum of 4 Other Senior Project Personnel are allowed
- A Minimum of 0 and Maximum of 10 Other Participating Organizations are allowed
- Submission of multiple Letters of Intent is not allowed

Full Proposal Preparation Instructions: Proposers may opt to submit proposals in response to this Program Solicitation via Grants.gov or via the NSF FastLane system.

- Full proposals submitted via FastLane: Proposals submitted in response to this program solicitation should be prepared and submitted in accordance with the general guidelines contained in the NSF Grant Proposal Guide (GPG). The complete text of the GPG is available electronically on the NSF website at: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg. Paper copies of the GPG may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from nsfpubs@nsf.gov. Proposers are reminded to identify this program solicitation number in the program solicitation block on the NSF Cover Sheet For Proposal to the National Science Foundation. Compliance with this requirement is critical to determining the relevant proposal processing guidelines. Failure to submit this information may delay processing.

- Full proposals submitted via Grants.gov: Proposals submitted in response to this program solicitation via Grants.gov should be prepared and submitted in accordance with the NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov. The complete text of the NSF Grants.gov Application Guide is available on the Grants.gov website and on the NSF website at: (http://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide). To obtain copies of the Application Guide and Application Forms Package, click on the Apply tab on the Grants.gov site, then click on the Apply Step 1: Download a Grant Application Package and Application Instructions link and enter the funding opportunity number, (the program solicitation number without the NSF prefix) and press the Download Package button. Paper copies of the Grants.gov Application Guide also may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from nsfpubs@nsf.gov.

In determining which method to utilize in the electronic preparation and submission of the proposal, please note the following:

Collaborative Proposals. All collaborative proposals submitted as separate submissions from multiple organizations must be submitted via the NSF FastLane system. Chapter II, Section D.5 of the Grant Proposal Guide provides additional information on collaborative proposals.

See Chapter II.C.2 of the GPG for guidance on the required sections of a full research proposal submitted to NSF. Please note that the proposal preparation instructions provided in this program solicitation may deviate from the GPG instructions.

Proposal Titles:

A proposal title must begin with "ICN-WEN:" For example, titles should take the form, **ICN-WEN: Title**. If you submit a proposal as part of a set of collaborative proposals, the title of the proposal should begin with "ICN-WEN:" followed by "Collaborative Research:", followed by the title. For example, if you are submitting a collaborative set of proposals, the title of each would be **ICN-WEN: Collaborative Research: Title**.

Project Description:

Describe the research and education activities to be undertaken in **up to 20 pages.** Note that additional documents listed under the Single Copy Documents and Supplementary Documents sections below do not count towards this page limit. All proposals are expected to:

- Describe how the project goals and research and education outcomes will have the potential to deliver a suitable co-design of Information-Centric Networks and future wireless networks to support beyond 5G (B5G) applications in the edge 'island' as defined in the solicitation;
- Clearly explain the research component(s) of the project;
- Present a plan to integrate research outcomes into education and more broadly advance education in the field;
- Include a plan for validation of the research providing quantitative results by simulation, experimentation, and prototyping;
- Provide plans for disseminating the research and education outcomes in a manner that enables the research community and helps scientists and engineers to use the results in ways that go beyond traditional academic publications;
- Provide a compelling rationale for the inclusion of each member of the team and, if the proposed project is a collaboration spanning multiple institutions, for the multi-institution structure of the project, as well as an explanation of how effective collaboration will be assured; and
- Present a research plan including **a Gantt chart** with major tasks, milestones, and interdependencies.

For all collaborative projects, Project Descriptions must be comprehensive and well-integrated, and should make a convincing case that the collaborative contributions of the project team will be greater than the sum of each of their individual contributions.

Single Copy Document: In the Single Copy Documents section, upload the following:

(1) A list of Collaborators: In lieu of the instructions specified in the GPG, Collaborators and Other Affiliations Information should be submitted as follows. (Note: In collaborative proposals, the lead institution should assemble and provide this information for all participants in the collaborative group):

Provide current, accurate information for all active or recent collaborators of personnel and institutions involved in the project. NSF staff will use this information in the merit review process to manage conflicts of interest. **This list is distinct from (1) below under Supplementary Documents in that it must include all active or recent Collaborators of all personnel involved with the proposed project.** Collaborators include any individual with whom any member of the project team -- including PIs, Co-PIs, Senior Personnel, paid/unpaid Consultants or Collaborators, Subawardees, Postdocs, and project-level advisory committee members -- has collaborated on a project, book, article, report, or paper within the preceding 48 months; or co-edited a journal, compendium, or conference proceedings within the preceding 24 months. This list should be numbered and include (in this order) Full name and Organization(s), with each item separated by a semi-colon. Each person listed should start a new numbered line.

1. Collaborators for Mary Smith; XYZ University; PI
    a. Helen Gupta; ABC University
    b. John Jones; University of PQR
    c. Fred Gonzales; DEF Corporation
    d. Susan White; DEF Corporation
2. Collaborators for John Jones; University of PQR; Senior Personnel
    a. Tim Green; ZZZ University
    b. Ping Chang, ZZZ University
    c. Mary Smith; XYZ University
3. Collaborators for Jane Brown; XYZ University; Postdoc
    a. Fred Gonzales; DEF Corporation
4. Collaborators for Bob Adams; ABC Community College; Paid Consultant
    a. None
5. Collaborators for Susan White; Welldone Institution; Unpaid Collaborator
    a. Mary Smith; XYZ University
    b. Harry Nguyen; Welldone Institution
6. Collaborators for Tim Green; ZZZ University; Subawardee
    a. John Jones; University of PQR

Supplementary Documents: In the Supplementary Documents section, upload the following information where relevant:

(1) A list of Project Personnel and Partner Institutions (Note: In separately-submitted collaborative proposals, only the lead institution should provide this information):

Provide current, accurate information for all personnel and institutions involved in the project. NSF staff will use this information in the merit review process to manage conflicts of interest. The list **must** include all PIs, Co-PIs, Senior Personnel, paid/unpaid Consultants or Collaborators, Subawardees, Postdocs, project-level advisory committee members, and writers of letters of support. This list should be numbered and include (in this order) Full name, Organization(s), and Role in the project, with each item separated by a semi-colon. Each person listed should start a new numbered line. For example:

1. Mary Smith; XYZ University; PI
2. John Jones; University of PQR; Senior Personnel
3. Jane Brown; XYZ University; Postdoc
4. Bob Adams; ABC Community College; Paid Consultant
5. Susan White; Welldone Institution; Unpaid Collaborator
6. Tim Green; ZZZ University; Subawardee

(2) Collaboration Plan:

Since the success of collaborative research efforts are known to depend on thoughtful coordination mechanisms that regularly bring together the various participants of the project, a Collaboration Plan is required for all proposals. Up to 2 pages are allowed for

Collaboration Plans. The length of and level of detail provided in the Collaboration Plan should be commensurate with the complexity of the proposed project. Where appropriate, the Collaboration Plan should include: 1) the specific roles of the project participants in all organizations involved; 2) information on how the project will be managed across all the investigators, institutions, and/or disciplines; 3) identification of the specific coordination mechanisms that will enable cross-investigator, cross-institution, and/or cross-discipline scientific integration (e.g., yearly workshops, graduate student exchange, project meetings at conferences, use of video-conferences, software repositories, etc.); and 4) specific references to the budget line items that support collaboration and coordination mechanisms. The Collaboration Plan should reference and support the project research plan, including key interdependencies between tasks for different PIs, outlined in the Project Description. However, note that the Collaboration Plan should **not** be used to expand discussions on proposed research activities; the activities themselves should be described within the Project Description section.

If a proposal does not include a Collaboration Plan of up to 2 pages, then that proposal will be returned without review.

(3) Postdoctoral Researcher Mentoring Plan (if applicable):

Each proposal that requests funding to support postdoctoral researchers must include, as a supplementary document, a description of the mentoring activities that will be provided for such individuals. In no more than one page, the mentoring plan must describe the mentoring that will be provided to all postdoctoral researchers supported by the project, irrespective of whether they reside at the submitting organization, any subawardee organization, or at any organization participating in a simultaneously submitted collaborative project. Please be advised that if required, FastLane will not permit submission of a proposal that is missing a Postdoctoral Researcher Mentoring Plan. See Chapter II.C.2.j of the GPG for further information about the implementation of this requirement.

(4) Data Management Plan (required):

Proposals must include a supplementary document of no more than two pages labeled "Data Management Plan." This supplementary document should describe how the proposal will conform to NSF policy on the dissemination and sharing of research results.

See Chapter II.C.2.j of the GPG for full policy implementation.

For additional information see: http://www.nsf.gov/bfa/dias/policy/dmp.jsp.

For specific guidance for proposals submitted to the Directorate for Computer and Information Science and Engineering (CISE) see: http://www.nsf.gov/cise/cise_dmp.jsp.

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

Budget Preparation Instructions:

Budgets for projects should include funding for one or more project representatives (PI/co-PI/senior researcher or NSF-approved replacement) and students to attend annual retreats/PI meetings held after the beginning of the award.

The budget submitted with the proposal should include all necessary project funds without regard to the two funding organizations; NSF and Intel will inform selected PIs of the breakdown in funding between the two organizations, and will request revised budgets at that point.

C. Due Dates

- **Letter of Intent Due Date(s) *(required)*** (due by 5 p.m. submitter's local time):

  September 20, 2016

- **Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):

  November 21, 2016

D. FastLane / Grants.gov Requirements

For Proposals Submitted Via FastLane:

To prepare and submit a proposal via FastLane, see detailed technical instructions available at: https://www.fastlane.nsf.gov/a1/newstan.htm. For FastLane user support, call the FastLane Help Desk at 1-800-673-6188 or e-mail fastlane@nsf.gov. The FastLane Help Desk answers general technical questions related to the use of the FastLane system. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this funding opportunity.

For Proposals Submitted Via Grants.gov:

Before using Grants.gov for the first time, each organization must register to create an institutional profile. Once registered, the applicant's organization can then apply for any federal grant on the Grants.gov website. Comprehensive information about using Grants.gov is available on the Grants.gov Applicant Resources webpage: http://www.grants.gov/web/grants/applicants.html. In addition, the NSF Grants.gov Application Guide (see link in Section V.A) provides instructions regarding the technical preparation of proposals via Grants.gov. For Grants.gov user support, contact the Grants.gov Contact Center at 1-800-518-4726 or by email: support@grants.gov. The Grants.gov Contact Center answers general technical questions related to the use of Grants.gov. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in

Section VIII of this solicitation.

Submitting the Proposal: Once all documents have been completed, the Authorized Organizational Representative (AOR) must submit the application to Grants.gov and verify the desired funding opportunity and agency to which the application is submitted. The AOR must then sign and submit the application to Grants.gov. The completed application will be transferred to the NSF FastLane system for further processing.

Proposers that submitted via FastLane are strongly encouraged to use FastLane to verify the status of their submission to NSF. For proposers that submitted via Grants.gov, until an application has been received and validated by NSF, the Authorized Organizational Representative may check the status of an application on Grants.gov. After proposers have received an e-mail notification from NSF, Research.gov should be used to check the status of an application.

VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES

Proposals received by NSF are assigned to the appropriate NSF program for acknowledgement and, if they meet NSF requirements, for review. All proposals are carefully reviewed by a scientist, engineer, or educator serving as an NSF Program Officer, and usually by three to ten other persons outside NSF either as *ad hoc* reviewers, panelists, or both, who are experts in the particular fields represented by the proposal. These reviewers are selected by Program Officers charged with oversight of the review process. Proposers are invited to suggest names of persons they believe are especially well qualified to review the proposal and/or persons they would prefer not review the proposal. These suggestions may serve as one source in the reviewer selection process at the Program Officer's discretion. Submission of such names, however, is optional. Care is taken to ensure that reviewers have no conflicts of interest with the proposal. In addition, Program Officers may obtain comments from site visits before recommending final action on proposals. Senior NSF staff further review recommendations for awards. A flowchart that depicts the entire NSF proposal and award process (and associated timeline) is included in the GPG as Exhibit III-1.

A comprehensive description of the Foundation's merit review process is available on the NSF website at: http://www.nsf.gov/bfa/dias/policy/merit_review/.

Proposers should also be aware of core strategies that are essential to the fulfillment of NSF's mission, as articulated in *Investing in Science, Engineering, and Education for the Nation's Future: NSF Strategic Plan for 2014-2018*. These strategies are integrated in the program planning and implementation process, of which proposal review is one part. NSF's mission is particularly well-implemented through the integration of research and education and broadening participation in NSF programs, projects, and activities.

One of the strategic objectives in support of NSF's mission is to foster integration of research and education through the programs, projects, and activities it supports at academic and research institutions. These institutions must recruit, train, and prepare a diverse STEM workforce to advance the frontiers of science and participate in the U.S. technology-based economy. NSF's contribution to the national innovation ecosystem is to provide cutting-edge research under the guidance of the Nation's most creative scientists and engineers. NSF also supports development of a strong science, technology, engineering, and mathematics (STEM) workforce by investing in building the knowledge that informs improvements in STEM teaching and learning.

NSF's mission calls for the broadening of opportunities and expanding participation of groups, institutions, and geographic regions that are underrepresented in STEM disciplines, which is essential to the health and vitality of science and engineering. NSF is committed to this principle of diversity and deems it central to the programs, projects, and activities it considers and supports.

A. Merit Review Principles and Criteria

The National Science Foundation strives to invest in a robust and diverse portfolio of projects that creates new knowledge and enables breakthroughs in understanding across all areas of science and engineering research and education. To identify which projects to support, NSF relies on a merit review process that incorporates consideration of both the technical aspects of a proposed project and its potential to contribute more broadly to advancing NSF's mission "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes." NSF makes every effort to conduct a fair, competitive, transparent merit review process for the selection of projects.

1. Merit Review Principles

These principles are to be given due diligence by PIs and organizations when preparing proposals and managing projects, by reviewers when reading and evaluating proposals, and by NSF program staff when determining whether or not to recommend proposals for funding and while overseeing awards. Given that NSF is the primary federal agency charged with nurturing and supporting excellence in basic research and education, the following three principles apply:

- All NSF projects should be of the highest quality and have the potential to advance, if not transform, the frontiers of knowledge.
- NSF projects, in the aggregate, should contribute more broadly to achieving societal goals. These "Broader Impacts" may be accomplished through the research itself, through activities that are directly related to specific research projects, or through activities that are supported by, but are complementary to, the project. The project activities may be based on previously established and/or innovative methods and approaches, but in either case must be well justified.
- Meaningful assessment and evaluation of NSF funded projects should be based on appropriate metrics, keeping in mind the likely correlation between the effect of broader impacts and the resources provided to implement projects. If the size of the activity is limited, evaluation of that activity in isolation is not likely to be meaningful. Thus, assessing the effectiveness of these activities may best be done at a higher, more aggregated, level than the individual project.

With respect to the third principle, even if assessment of Broader Impacts outcomes for particular projects is done at an aggregated level, PIs are expected to be accountable for carrying out the activities described in the funded project. Thus, individual projects should include clearly stated goals, specific descriptions of the activities that the PI intends to do, and a plan in place to document the outputs of those activities.

These three merit review principles provide the basis for the merit review criteria, as well as a context within which the users of the criteria can better understand their intent.

2. Merit Review Criteria

All NSF proposals are evaluated through use of the two National Science Board approved merit review criteria. In some instances, however, NSF will employ additional criteria as required to highlight the specific objectives of certain programs and activities.

The two merit review criteria are listed below. **Both** criteria are to be given **full consideration** during the review and decision-making processes; each criterion is necessary but neither, by itself, is sufficient. Therefore, proposers must fully address both criteria. (GPG Chapter II.C.2.d.i. contains additional information for use by proposers in development of the Project Description section of the proposal.) Reviewers are strongly encouraged to review the criteria, including GPG Chapter II.C.2.d.i., prior to the review of a proposal.

When evaluating NSF proposals, reviewers will be asked to consider what the proposers want to do, why they want to do it, how they plan to do it, how they will know if they succeed, and what benefits could accrue if the project is successful. These issues apply both to the technical aspects of the proposal and the way in which the project may make broader contributions. To that end, reviewers will be asked to evaluate all proposals against two criteria:

- **Intellectual Merit:** The Intellectual Merit criterion encompasses the potential to advance knowledge; and
- **Broader Impacts:** The Broader Impacts criterion encompasses the potential to benefit society and contribute to the achievement of specific, desired societal outcomes.

The following elements should be considered in the review for both criteria:

1. What is the potential for the proposed activity to
    a. Advance knowledge and understanding within its own field or across different fields (Intellectual Merit); and
    b. Benefit society or advance desired societal outcomes (Broader Impacts)?
2. To what extent do the proposed activities suggest and explore creative, original, or potentially transformative concepts?
3. Is the plan for carrying out the proposed activities well-reasoned, well-organized, and based on a sound rationale? Does the plan incorporate a mechanism to assess success?
4. How well qualified is the individual, team, or organization to conduct the proposed activities?
5. Are there adequate resources available to the PI (either at the home organization or through collaborations) to carry out the proposed activities?

Broader impacts may be accomplished through the research itself, through the activities that are directly related to specific research projects, or through activities that are supported by, but are complementary to, the project. NSF values the advancement of scientific knowledge and activities that contribute to achievement of societally relevant outcomes. Such outcomes include, but are not limited to: full participation of women, persons with disabilities, and underrepresented minorities in science, technology, engineering, and mathematics (STEM); improved STEM education and educator development at any level; increased public scientific literacy and public engagement with science and technology; improved well-being of individuals in society; development of a diverse, globally competitive STEM workforce; increased partnerships between academia, industry, and others; improved national security; increased economic competitiveness of the United States; and enhanced infrastructure for research and education.

Proposers are reminded that reviewers will also be asked to review the Data Management Plan and the Postdoctoral Researcher Mentoring Plan, as appropriate.

Additional Solicitation Specific Review Criteria

NSF engages in partnership programs with companies in order to increase the potential for research discoveries to become innovations with societal impact through market mechanisms.

In this light, solicitation-specific review criteria include:

- **Technical innovation, non-incremental potential, and relevance.** The extent to which the proposal's problem formulation and key approaches are innovative, important, and relevant to the problem at hand in addressing *the three dimensions identified in the Program Description*, and more specifically the degree to which the project's technical research is likely to inform the realization of wireless network architectures that are demonstrably more effective at flexibly serving new applications such as the Internet of Things, tactile Internet, etc.;
- **Clarity of overall objectives, intermediate goals, and success criteria**. All teams are expected to demonstrate progress toward project goals on a quarterly basis and the extent to which these goals are articulated will be considered in evaluating proposals;
- **Collaboration**. The extent of planned collaboration for sufficient exploration and subsequent refined focus to ensure the success of the project; if the proposal involves a collaboration spanning multiple institutions, the compelling rationale for the multi-institution structure of the project, and the explanation of how effective collaboration will be assured; and
- **Cost effectiveness and cost realism**. The extent to which the proposed work can, within the proposed resource levels, both pursue the development of a systems perspective and implement demonstrations of interrelated component research ideas; these demonstrations, along with the research outcomes, should serve as a call to action by the ICN and 5G wireless innovation ecosystem.

B. Review and Selection Process

Proposals submitted in response to this program solicitation will be reviewed by Ad hoc Review and/or Panel Review, Reverse Site Review, or Internal Review by Intel Corporation.

Intel and NSF will each conduct separate proposal reviews. For Intel, internal review will be conducted, and will consider the degree to which proposals have a substantial potential for influencing the direction of Intel's long-range technology plans, as well as industry ecosystem plans for ICN and wireless innovation. Also, Intel has a strong commitment to broadening participation, as does NSF (http://www.nsf.gov/od/broadeningparticipation/bp.jsp), and will provide the same considerations as NSF to the diversity of the proposer team in the evaluation of the proposals. Proposals and other relevant information about proposals including reviews will be shared between the participating organizations as appropriate. Upon conclusion of the separate reviews, award recommendations will be coordinated by a Joint NSF and Intel Working Group (hereafter referred to as JWG) comprising personnel from both NSF and Intel. The JWG will recommend meritorious proposals for award.

Reviewers will be asked to evaluate proposals using two National Science Board approved merit review criteria and, if applicable, additional program specific criteria. A summary rating and accompanying narrative will generally be completed and submitted by each reviewer and/or panel. The Program Officer assigned to manage the proposal's review will consider the advice of reviewers and will formulate a recommendation.

After scientific, technical and programmatic review and consideration of appropriate factors, the NSF Program Officer recommends to the cognizant Division Director whether the proposal should be declined or recommended for award. NSF strives to be able to tell applicants whether their proposals have been declined or recommended for funding within six months. Large or particularly complex proposals or proposals from new awardees may require additional review and processing time. The time interval begins on the deadline or target date, or receipt date, whichever is later. The interval ends when the Division Director acts upon the Program Officer's recommendation.

After programmatic approval has been obtained, the proposals recommended for funding will be forwarded to the Division of Grants and Agreements for review of business, financial, and policy implications. After an administrative review has occurred, Grants and Agreements Officers perform the processing and issuance of a grant or other agreement. Proposers are cautioned that only a Grants and Agreements Officer may make commitments, obligations or awards on behalf of NSF or authorize the expenditure of funds. No commitment on the part of NSF should be inferred from technical or budgetary discussions with a NSF Program Officer. A Principal Investigator or organization that makes financial or personnel commitments in the absence of a grant or cooperative agreement signed by the NSF Grants and Agreements Officer does so at their own risk.

Once an award or declination decision has been made, Principal Investigators are provided feedback about their proposals. In all cases, reviews are treated as confidential documents. Verbatim copies of reviews, excluding the names of the reviewers or any reviewer-identifying information, are sent to the Principal Investigator/Project Director by the Program Officer. In addition, the proposer will receive an explanation of the decision to award or decline funding.

VII. AWARD ADMINISTRATION INFORMATION

A. Notification of the Award

Notification of the award is made to *the submitting organization* by a Grants Officer in the Division of Grants and Agreements. Organizations whose proposals are declined will be advised as promptly as possible by the cognizant NSF Program administering the program. Verbatim copies of reviews, not including the identity of the reviewer, will be provided automatically to the Principal Investigator. (See Section VI.B. for additional information on the review process).

B. Award Conditions

An NSF award consists of: (1) the award notice, which includes any special provisions applicable to the award and any numbered amendments thereto; (2) the budget, which indicates the amounts, by categories of expense, on which NSF has based its support (or otherwise communicates any specific approvals or disapprovals of proposed expenditures); (3) the proposal referenced in the award notice; (4) the applicable award conditions, such as Grant General Conditions (GC-1)*; or Research Terms and Conditions* and (5) any announcement or other NSF issuance that may be incorporated by reference in the award notice. Cooperative agreements also are administered in accordance with NSF Cooperative Agreement Financial and Administrative Terms and Conditions (CA-FATC) and the applicable Programmatic Terms and Conditions. NSF awards are electronically signed by an NSF Grants and Agreements Officer and transmitted electronically to the organization via e-mail.

*These documents may be accessed electronically on NSF's Website at http://www.nsf.gov/awards/managing/award_conditions.jsp?org=NSF. Paper copies may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from nsfpubs@nsf.gov.

More comprehensive information on NSF Award Conditions and other important information on the administration of NSF awards is contained in the NSF *Award & Administration Guide* (AAG) Chapter II, available electronically on the NSF Website at http://www.nsf.gov/publications/pub_summ.jsp?ods_key=aag.

Special Award Conditions:

Each awarded project will be jointly funded by NSF and Intel through separate NSF and Intel funding instruments. NSF awards will be made as continuing or standard grants. Intel awards will be made as Intel agreements (i.e., contracts, grants or gifts). NSF and Intel will manage their respective awards/agreements in accordance with their own guidelines and regulations.

1. **Site visits, PI meetings, and annual retreats**

   Awardees are expected to organize an annual PI meeting/annual retreat, which all awardees under this solicitation are expected to attend. NSF and Intel personnel who have interest in the programs will attend this meeting. The meeting will involve reviews of the research underway in each project along with presentations from NSF and Intel on technical areas of interest related to each awarded project. Ample time will be provided for face-to-face interaction between participants during these retreats. Intel and NSF will work with academic leadership to organize these events. Proposers should include the costs for at least three project participants to attend each annual PI meeting in the travel portion of the budget. Each PI team should also budget for the cost of hosting one of the annual PI meetings by including appropriate costs for running a 2-day meeting with 20 participants in the Participant Support Costs portion of the proposed budget. For collaborative proposals, the cost of hosting the PI meeting should be present in the budget of the lead institution's proposal.

2. **Intellectual property, publishing, and licensing**

   Awardees will be required to include appropriate acknowledgment of NSF and Intel support in reports and/or publications on work performed under the award. An example of such an acknowledgement would be: "This material is based upon work supported by NSF/Intel Partnership on Information-Centric Networking in Wireless Edge Networks Program under Award Title and No. [Recipient enters project title and awards number(s)]."

   All projects agree to distribute all source code that has been authored while working on an NSF/Intel award under a BSD, Apache or other equivalent open source license. Software licenses that require as a condition of use, modification and/or distribution that the software or other software incorporated into, derived from or distributed with the software be licensed by the user to third parties for the purpose of making and/or distributing derivative works are not permitted. Licenses not

appropriate thus include any version of GNU's General Public License (GPL) or Lesser/Library GPL (LGPL), the Artistic License (e.g., PERL), and the Mozilla Public License.

Projects that generate data or software in performing the work under an award agree not to incorporate into said data or software, except by separate prearrangement with NSF and Intel, any third-party code or background intellectual property that would limit or restrict the ability to distribute said data or software under an open source license.

Awardees may file patent applications, providing that they grant to Intel a non-exclusive, worldwide, royalty-free, sub-licensable license to all intellectual property rights in any inventions or works of authorship resulting from research conducted under the joint award.

All awarded projects must maintain a website that is updated on a monthly basis with the specifics of progress on the projects.

3. **Intel participation in research**

Intel may separately fund its own personnel to directly participate in NSF/Intel Partnership research, part-time or full-time, with the universities awarded NSF/Intel Partnership projects. Proposals do not need to budget for the cost of such personnel. These Intel researchers will work alongside the academic researchers, identifying opportunities for tech transfer, and being involved with the projects as advisors or as fellow researchers. Optional deployment of Intel Researchers in Residence (RinR) on campuses will require mutual consent by the Parties and respective awardees in the Project Management Plan for each NSF/Intel Partnership award. Further, Intel may designate one of its more senior, separately-funded researchers to work alongside NSF/Intel Partnership academic lead PIs. The Intel ICN-WEN Program Director and the lead Intel researcher may work with the academic PI of each project to collaboratively oversee the project, manage Intel's participation in each project, champion considerations related to innovation – the translation of discoveries into industry impact – and manage the center on a day-by-day basis. He/she would inject a perspective on commercial aspects and help with the day-to-day leadership of the center. He/she would also be responsible for working with the Intel Program Director to oversee the engagement of all other Intel researchers.

4. **Program management**

The Intel ICN-WEN Program Director overseeing funded projects may become a member of the Project Management Team for the Intel award. Intel may choose to organize, at its own expense, additional retreats in collaboration with NSF and may require deliverable reports to monitor project progress. Annual reviews may be conducted jointly by NSF and Intel in conjunction with the PI meetings. Intel may lead the organization of semi-annual phone calls with project teams, with NSF participation. NSF and Intel may request visits to the research institutions or may ask PIs to visit NSF or Intel.

5. **Funding Support and Budget Revisions**

Individual awards selected for joint funding by NSF and Intel will be funded through separate NSF and Intel funding instruments. For each such project, NSF support will be provided via an NSF grant and Intel support will be provided via an Intel agreement (i.e., contract, grant or gift). Either organization may supplement a project without requiring the other party to provide any additional funds.

The budget submitted with the proposal should include all necessary project funds without regard to the two funding organizations; NSF and Intel will inform selected PIs of the breakdown in funding between the two organizations, and will request revised budgets at that point.

C. Reporting Requirements

For all multi-year grants (including both standard and continuing grants), the Principal Investigator must submit an annual project report to the cognizant Program Officer no later than 90 days prior to the end of the current budget period. (Some programs or awards require submission of more frequent project reports). No later than 120 days following expiration of a grant, the PI also is required to submit a final project report, and a project outcomes report for the general public.

Failure to provide the required annual or final project reports, or the project outcomes report, will delay NSF review and processing of any future funding increments as well as any pending proposals for all identified PIs and co-PIs on a given award. PIs should examine the formats of the required reports in advance to assure availability of required data.

PIs are required to use NSF's electronic project-reporting system, available through Research.gov, for preparation and submission of annual and final project reports. Such reports provide information on accomplishments, project participants (individual and organizational), publications, and other specific products and impacts of the project. Submission of the report via Research.gov constitutes certification by the PI that the contents of the report are accurate and complete. The project outcomes report also must be prepared and submitted using Research.gov. This report serves as a brief summary, prepared specifically for the public, of the nature and outcomes of the project. This report will be posted on the NSF website exactly as it is submitted by the PI.

More comprehensive information on NSF Reporting Requirements and other important information on the administration of NSF awards is contained in the NSF *Award & Administration Guide* (AAG) Chapter II, available electronically on the NSF Website at http://www.nsf.gov/publications/pub_summ.jsp?ods_key=aag.

In addition, Intel may require deliverable reports to monitor project progress.

VIII. AGENCY CONTACTS

Please note that the program contact information is current at the time of publishing. See program website for any updates to the points of contact.

General inquiries regarding this program should be made to:

- Thyagarajan Nandagopal, Program Director, NSF CISE/CNS, telephone: (703) 292-8950, email: tnandago@nsf.gov
- Darleen L. Fisher, Program Director, NSF CISE/CNS, telephone: (703) 292-8950, email: dlfisher@nsf.gov
- David Corman, Program Director, NSF CISE/CNS, telephone: (703) 292-8950, email: dcorman@nsf.gov
- Jeff Foerster, Director, Emerging Connectivity Systems Research, Intel Labs, telephone: (503) 264-6859, email: jeffrey.r.foerster@intel.com
- David Ott, Program Director, Intel Labs, telephone: (480) 554-7868, email: david.e.ott@intel.com

For questions related to the use of FastLane, contact:

- FastLane Help Desk, telephone: 1-800-673-6188; e-mail: fastlane@nsf.gov.

For questions relating to Grants.gov contact:

- Grants.gov Contact Center: If the Authorized Organizational Representatives (AOR) has not received a confirmation message from Grants.gov within 48 hours of submission of application, please contact via telephone: 1-800-518-4726; e-mail: support@grants.gov.

IX. OTHER INFORMATION

The NSF website provides the most comprehensive source of information on NSF Directorates (including contact information), programs and funding opportunities. Use of this website by potential proposers is strongly encouraged. In addition, "NSF Update" is an information-delivery system designed to keep potential proposers and other interested parties apprised of new NSF funding opportunities and publications, important changes in proposal and award policies and procedures, and upcoming NSF Grants Conferences. Subscribers are informed through e-mail or the user's Web browser each time new publications are issued that match their identified interests. "NSF Update" also is available on NSF's website.

Grants.gov provides an additional electronic capability to search for Federal government-wide grant opportunities. NSF funding opportunities may be accessed via this mechanism. Further information on Grants.gov may be obtained at http://www.grants.gov.

ABOUT INTEL LABS

As an industry leader, Intel pushes the boundaries of technology to make amazing experiences possible for every person on earth. From powering the latest devices and the cloud you depend on to driving policy, diversity, sustainability, and education, Intel creates value for its stockholders, customers, and society. Intel expects the suppliers in its supply chain to be strong partners in making Intel successful through support of Intel's goals and commitments to diversity, sustainability, and education.

Intel Labs is Intel's corporate research and development group with a charter to deliver breakthrough innovations to fuel Intel's growth and technology leadership. Intel Labs focuses its research in the areas of architecture and design, software and systems, security, integrated computing and user experience. Intel Labs is comprised of a worldwide network of research centers in nine countries including the U.S., China, India, Ireland, Israel, Germany, Mexico, Taiwan and UK. Its research has led to important Intel products and tech leadership including Xeon Phi, vPro, Atom, Thunderbolt and Quark.

Intel Labs collaborates with industry partners, government and academia throughout the world to leverage the brightest minds in research. Intel Labs encourages open and collaborative innovation with researchers through its network of university-centered Intel Science and Technology Centers (ISTCs) in the U.S. and Intel Collaborative Research Institutes (ICRIs) abroad focused on projects aligned with Intel Labs' overall research agenda.

ABOUT THE NATIONAL SCIENCE FOUNDATION

The National Science Foundation (NSF) is an independent Federal agency created by the National Science Foundation Act of 1950, as amended (42 USC 1861-75). The Act states the purpose of the NSF is "to promote the progress of science; [and] to advance the national health, prosperity, and welfare by supporting research and education in all fields of science and engineering."

NSF funds research and education in most fields of science and engineering. It does this through grants and cooperative agreements to more than 2,000 colleges, universities, K-12 school systems, businesses, informal science organizations and other research organizations throughout the US. The Foundation accounts for about one-fourth of Federal support to academic institutions for basic research.

NSF receives approximately 55,000 proposals each year for research, education and training projects, of which approximately 11,000 are funded. In addition, the Foundation receives several thousand applications for graduate and postdoctoral fellowships. The agency operates no laboratories itself but does support National Research Centers, user facilities, certain oceanographic vessels and Arctic and Antarctic research stations. The Foundation also supports cooperative research between universities and industry, US participation in international scientific and engineering efforts, and educational activities at every academic level.

Facilitation Awards for Scientists and Engineers with Disabilities provide funding for special assistance or equipment to enable persons with disabilities to work on NSF-supported projects. See Grant Proposal Guide Chapter II, Section D.2 for instructions regarding preparation of these types of proposals.

The National Science Foundation has Telephonic Device for the Deaf (TDD) and Federal Information Relay Service (FIRS) capabilities that enable individuals with hearing impairments to communicate with the Foundation about NSF programs, employment or general information. TDD may be accessed at (703) 292-5090 and (800) 281-8749, FIRS at (800) 877-8339.

The National Science Foundation Information Center may be reached at (703) 292-5111.

The National Science Foundation promotes and advances scientific progress in the United States by competitively awarding grants and cooperative agreements for research and education in the sciences, mathematics, and engineering.

To get the latest information about program deadlines, to download copies of NSF publications, and to access abstracts of awards, visit the NSF Website at http://www.nsf.gov

- **Location:** 4201 Wilson Blvd. Arlington, VA 22230
- **For General Information** (NSF Information Center)**:** (703) 292-5111
- **TDD (for the hearing-impaired):** (703) 292-5090
- **To Order Publications or Forms:**

  Send an e-mail to: nsfpubs@nsf.gov

  or telephone: (703) 292-7827
- **To Locate NSF Employees:** (703) 292-5111

PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

The information requested on proposal forms and project reports is solicited under the authority of the National Science Foundation Act of 1950, as amended. The information on proposal forms will be used in connection with the selection of qualified proposals; and project reports submitted by awardees will be used for program evaluation and reporting within the Executive Branch and to Congress. The information requested may be disclosed to qualified reviewers and staff assistants as part of the proposal review process; to proposer institutions/grantees to provide or obtain data regarding the proposal review process, award decisions, or the administration of awards; to government contractors, experts, volunteers and researchers and educators as necessary to complete assigned work; to other government agencies or other entities needing information regarding applicants or nominees as part of a joint application review process, or in order to coordinate programs or policy; and to another Federal agency, court, or party in a court or Federal administrative proceeding if the government is a party. Information about Principal Investigators may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records," 69 Federal Register 26410 (May 12, 2004), and NSF-51, "Reviewer/Proposal File and Associated Records," 69 Federal Register 26410 (May 12, 2004). Submission of the information is voluntary. Failure to provide full and complete information, however, may reduce the possibility of receiving an award.

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