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Request for Information on the National Digital Twins R&D Strategic Plan

ARA PAWR Rural Wireless Living Lab

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Before the
NITRD National Coordination Office
Washington, D.C. 20024

In the Matter of	)
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National Digital Twins R&D Strategic Plan	)

Digital Twins for and by Rural Broadband[1]

— Comments by ARA PAWR Rural Wireless Living Lab

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[redacted]

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About ARA PAWR Rural Wireless Living Lab

The National Science Foundation Platforms for Advanced Wireless Research (NSF PAWR) program has been supporting the development and operation of the ARA rural wireless living lab to enable research, education, and innovation in agriculture- and rural-focused wireless technologies and applications. ARA is committed to the development and deployment of 5G-and-beyond technologies for rural America, and it is led by the Iowa State University (ISU) Center for Wireless, Communities and Innovation (WiCI). The mission of WiCI is to advance the frontiers of wireless systems and applications while addressing the broadband gap between rural and urban regions at the same time. To this end, WiCI has been collaborating with 65+ public-private partners from industry, academia, government, and communities to drive ARA-enabled wireless and applications technology development, deployment, and adoption, and it serves as a neutral entity in wireless research, education, and innovation. WiCI is a member of the O-RAN Alliance and Next G Alliance, and it has led the establishment of the ARA O-RAN Open Testing and Integration Center (ARA OTIC) to focus on Open RAN for rural America.

ARA deploys advanced wireless, edge, and cloud equipment across the Iowa State University (ISU) campus, City of Ames (where ISU resides), and surrounding research and producer farms as well as rural communities in central Iowa, spanning hundreds of square miles of rural area [1]. Wireless platforms featured by ARA have demonstrated promising performance so far, for instance, up to 3 Gbps

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wireless access throughput, up to 10 km effective cell radius, and close to 10 Gbps throughput across a wireless backhaul link of over 10 km.

Digital twins and AI/ML are two focus areas of ARA and WiCI. WiCI has expertise in developing digital twins for wireless systems as well as connected and automated vehicles, and WiCI is leading activities that use advanced wireless systems for supporting digital twin initiatives such as those for agriculture.

More information about ARA and WiCI can be found at arawireless.org and [redacted] respectively, and inquires can be emailed to [redacted]

Comments on National Digital Twins R&D Strategic Plan: Perspectives from Rural Broadband and Rural Industries

An effective National Digital Twins R&D Strategic Plan is critical to expediting the develop and deployment of digital twins in diverse sectors such as manufacturing, agriculture, renewable energy, transportation, defense, scientific exploration, and education. As we formulate the National Digital Twins R&D Strategic Plan, it is important to pay attention to the unique needs of diverse sectors while addressing the foundational mathematical, statistical, and computational challenges. In particular, ***the rural America presents unique needs for digital twins, and it highlights the urgency of addressing rural broadband both as an application domain and as the virtual-physical communications foundation for rural digital twins in general.*** Specifically, industries such as agriculture and manufacturing can benefit significantly from digital twins, and the realization of these rural industry digital twins relies on real-time communications between sensors and actuators in factories/farms and digital twins at edge/cloud. However, there lacks broadband connectivity to agriculture farms and remote factories. In the meantime, to address the rural broadband challenge, advanced wireless systems are critical [1], and multi-timescale digital twins are critical for the planning and real-time optimization of these wireless systems.

Based on the above observations, it is critical that the Digital Twins R&D Strategic Plan keeps in mind the unique needs and opportunities provided by rural America, with a special focus on rural broadband, rural industries (e.g., agriculture, manufacturing, and renewable energy), as well as workforce development as we explain in more detail below:

- **Data: ARA as source of ground-truth data for rural wireless digital twin.** ARA [1] is the first-of-its-kind wireless living lab for rural wireless systems. It features state-of-the-art wireless access and x-haul wireless platforms (e.g., full-programmable software-defined radios together with open-source 5G/Next-G source platforms at 3.4 – 3.6 GHz band, configurable COTS 5G massive MIMO systems at 3.45 – 3.55 GHz and 28 GHz bands, programmable massive MIMO systems at the TVWS band, as well as configurable 11 GHz, 80 GHz, and 194 THz x-hauls) as well as LEO satellite communications user terminals deployed in real-world agriculture farms and rural community settings [2,3,4]. Therefore, ARA offers unique opportunities of collecting ground-truth data for rural wireless systems, which in turn helps drive digital twin model development and validation. ARA has built-in mechanisms for data storage and sharing, as well as experiment reproducibility, and these mechanisms make ARA an invaluable platform for driving digital twins development for wireless systems.

- **Ecosystem: from rural wireless to rural industries**. Besides wireless platforms, the ARA wireless living lab features real-world agriculture farms for research, education, and production use, and it also includes a bioprocessing plant as well as a mechanical systems design, prototyping, and manufacturing facility, representing bioprocessing and heavy metal industrial settings. Therefore, the ARA wireless living lab can be used to foster cross-sector collaborative digital twins initiatives across wireless and its applications in agriculture and manufacturing.
- **Long Term & Standards:** Given that we are still at the early stage of research and practice in digital twining and that a wide range of policy and technology innovations need to be nurtured and field-tested before their adoption in practice, it will be invaluable to leverage the existing ARA PAWR platform (i.e., both wireless and edge compute resources) to develop sustainable test and evaluation infrastructures for the development of rural-focused digital twins. Besides the hardware and software infrastructures, it is important to engage the diverse stakeholder communities ranging from researchers to application developers, agriculture and rural users, as well as local and state government agencies in developing relevant policies, processes, and standards.
- **Workforce**: Given that digital twining is a new field of innovation and practice, rural-focused technology and policy innovation is critical, which in turn calls for *rural-focused workforce development and innovation capacity building*. To this end, the workforce development aspect of the National Digital Twins R&D Strategic Plan shall have a rural focus and engage rural stakeholders including research and education organizations (e.g., WiCI) and their partners. Specific action areas include *1) developing innovation capacity within the rural regions* so that rural-focused digital twin innovations progress in parallel with urban-focused innovations, and 2) *engaging and empowering rural-regions in digital twin innovations* such as those related to rural broadband, agriculture, manufacturing, and renewable energy.

References

[1] H. Zhang *et al.*, "ARA: A Wireless Living Lab Vision for Smart and Connected Rural Communities," in *ACM Workshop on Wireless Network Testbeds, Experimental evaluation and CHaracterization (WiNTECH)*, 2021.

[2] T. Ul Islam *et al.*, "AraMIMO: Programmable TVWS mMIMO Living Lab for Rural Wireless," in *ACM Workshop on Wireless Network Testbeds, Experimental evaluation and CHaracterization (WiNTECH)*, 2023.

[3] G. Zu *et al.*, "AraHaul: Multi-Modal Wireless X-Haul Living Lab for Long-Distance, High-Capacity Communications," in *IEEE Future Networks World Forum (FNWF)*, 2023.

[4] T. Zhang *et al.*, "Exploring Wireless Channels in Rural Areas: A Comprehensive Measurement Study," in *IEEE Future Networks World Forum (FNWF)*, 2023.