Connecting the Unconnected: from Challenges to Opportunities

Hongwei Zhang

hongwei@iastate.edu, +1 515 294 2143

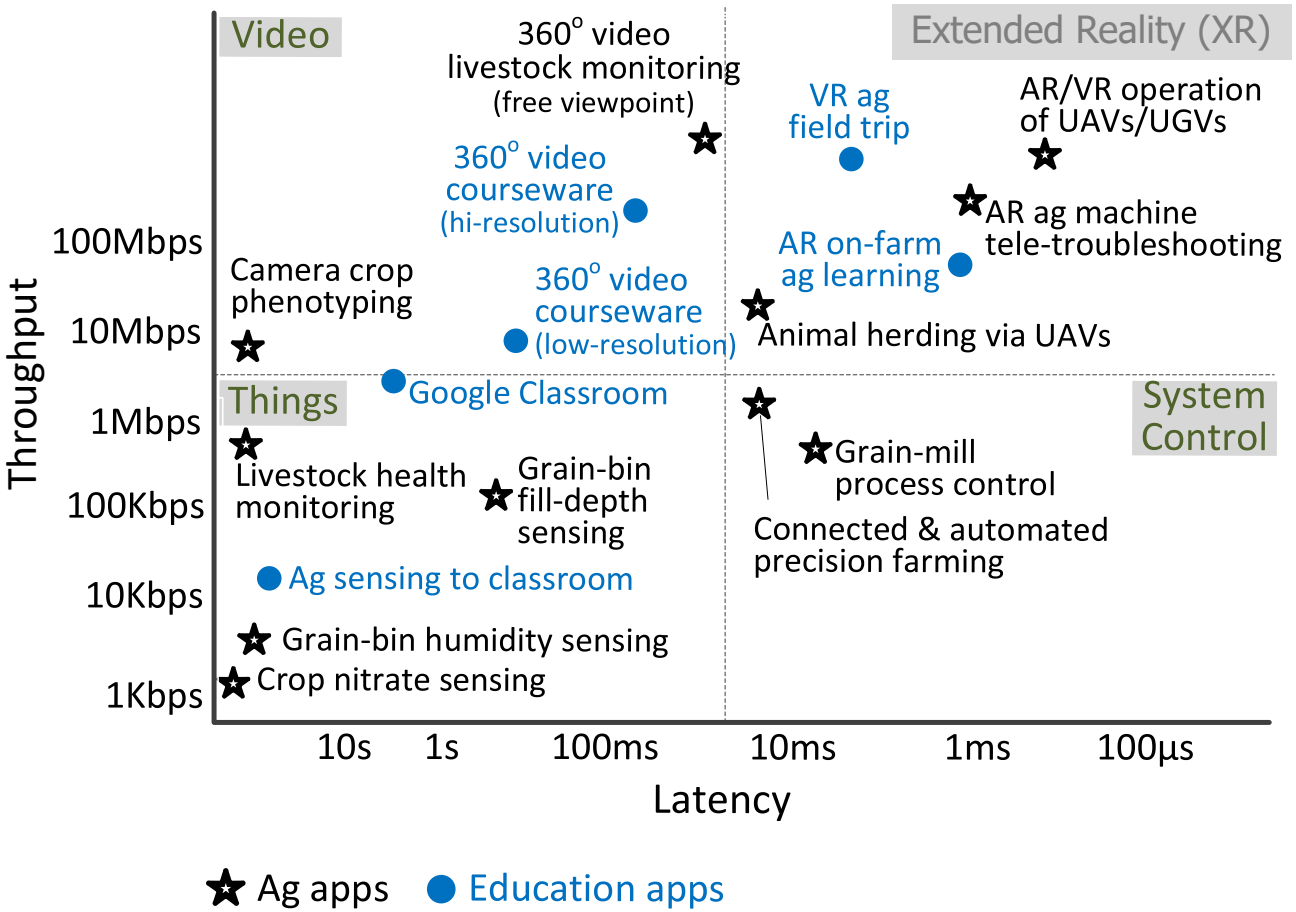
http://www.ece.iastate.edu/~hongwei

IOWA STATE UNIVERSITY
Electrical and Computer Engineering

Rural Broadband Challenge in U.S.

- Rural U.S. as a foundation for the country
  - 72% of the nation's land and 46 million people
  - Home to agriculture, manufacturing, renewable energy industries etc
    - Major source of food and energy & $750+ billion contribution to annual GDP
- Lack of universal, affordable rural broadband
  - 39% of rural U.S. lacks broadband access
  - Most ag farms are not connected at all

Opportunity for Broadband Application & Innovation



ARA: Wireless Living Lab for Smart and Connected Rural Communities

www.arawireless.org

- ARA: southern constellation of stars in astronomy; agriculture and rural Communities.
- The image of Ara (upper-right corner of the image above) shows the way rural wireless is expected to look like, that is, with disk-like wireless access networks connected by long-distance wireless backhauls.
- The light in the sky from the Ara stars also signifies the vision of “ARA as the light for rural wireless and broadband”.
- $16M investment from NSF Platforms for Advanced Wireless Research (PAWR) program

ARA Deployment in Central Iowa

helikite

AraHaul sites each with 1+ AraRANs

AraRANs around Ames

Long-Distance, High-Throughput Communications

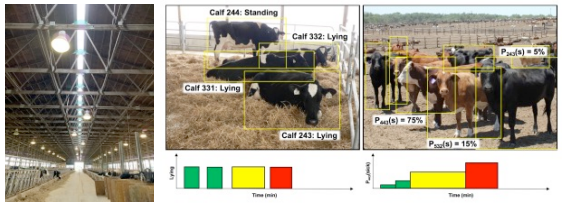
- **AraHaul**: multi-modal, long-distance, high-throughput systems
  - Terrestrial communications
    - Optical (AraOptical) 160Gbps 15km+
    - mmWave (Aviat WTM 4800) 20Gbps 15km+
    - Microwave (Aviat WTM 4200) 2.5Gbps 20km+
    - Multi-band (Aviat WTM 4811) 2.5-20Gbps 15km+
  - LEO satellite communications 100Mbps across planet
- Capabilities enabled
  - *Spatial, temporal, and spectral channel diversity* for *robust* high-capacity
  - *RaptorQ rateless coding* for *real-time* bandwidth aggregation

- **AraRAN**: high-throughput COTS & SDR systems
  - Low-UHF mMIMO (Skylark) 100Mbps+ 10km+
  - mmWave (NI, InterDigital, Ericsson) 100Mbps+ 150m+
  - sub-7GHz (NI, Ericsson) 50Mbps+ 1km+
- Capabilities enabled
  - bandwidth aggregation, channel aggregation & bonding
  - mMIMO
  - Waveforms beyond OFDM
  - Dynamic spectrum sharing
  - Edge computing

Deployment for Agriculture

- Ag environment: crop & livestock farms, research & producer farms


Crop farms



Livestock farms


Grain mill


Biorefinery


Barn

- Ag equipment and use cases

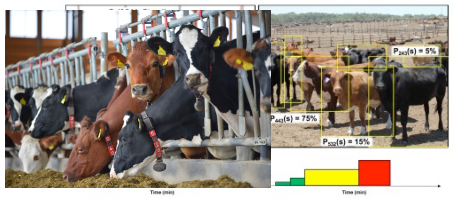

20+ ag machines


ag robots

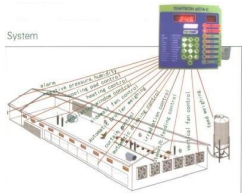

UAVs


1,000+ camera


160+ crop/soil sensors etc


100+ cameras, 450+ ear tags


Ground & aerial vehicles



Environmental sensing & control


solar farm

Deployment for Rural Communities

- Ag, rural, and community infrastructures & environment

Grain bin

Power plant

Water towers

Municipal airport

Traffic infrastructure

State/community/ industry wireless towers

School buildings

Football stadium

- Community equipment and use cases

Police car

City well

School bus

UAV

Laptop, tablet, phone etc

Diverse Wireless Channels in Central Iowa

Four-Season Weather

Sunny

Rainy

Foggy

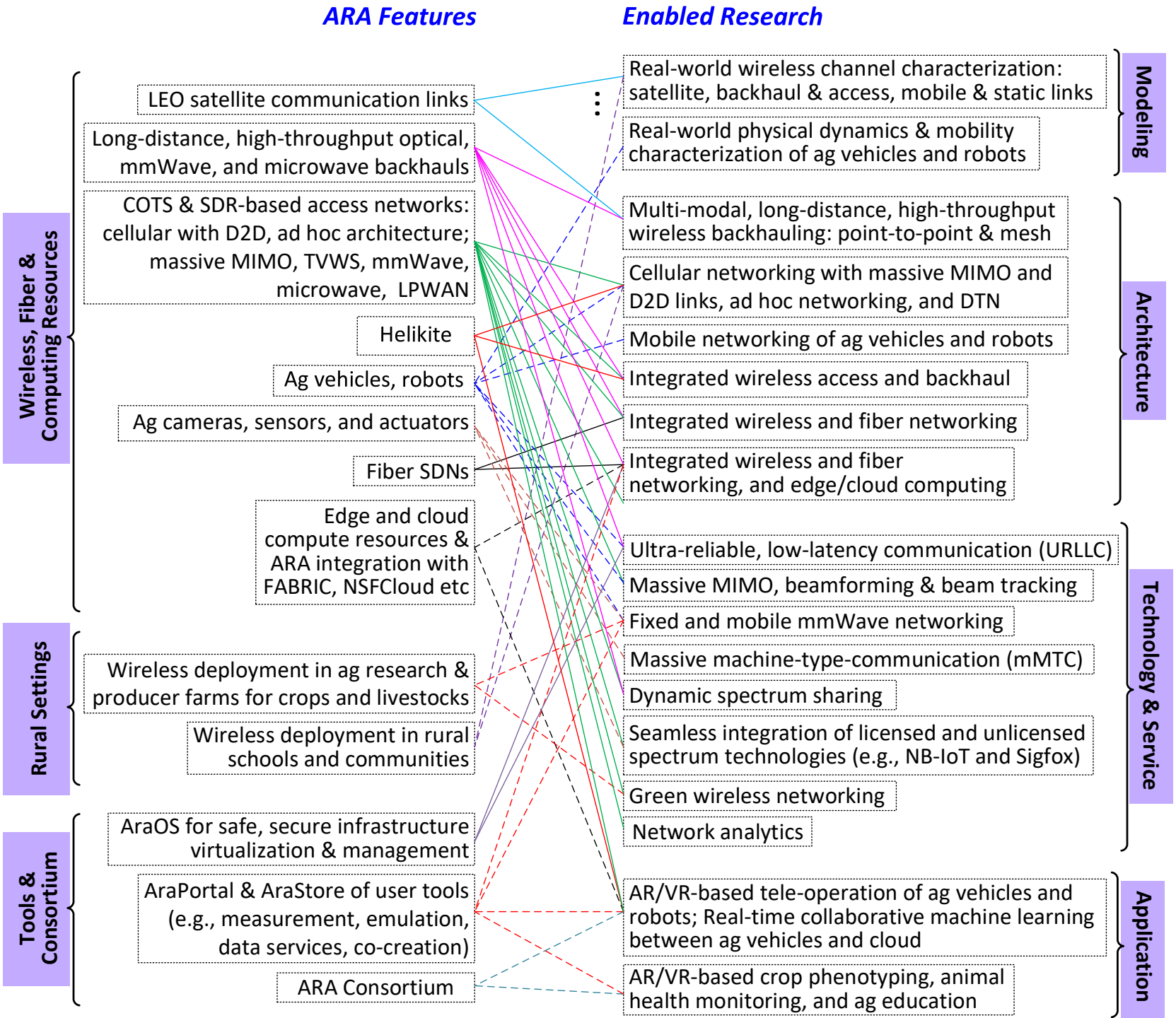
Snowy

Diverse Rural Terrain

Flat prairie

Rolling hills with spatio-temporally-varying foliage

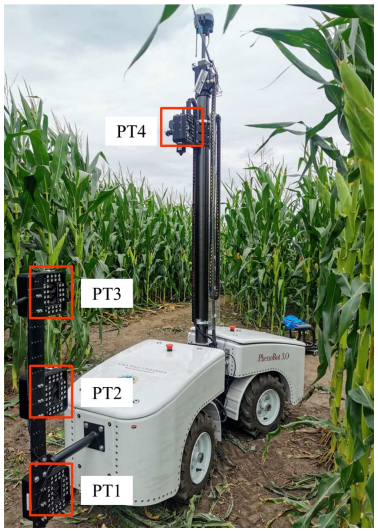
Rural town


ARA Features
Enabled Research
Wireless, Fiber & Computing Resources
LEO satellite communication links
Long-distance, high-throughput optical, mmWave, and microwave backhauls
COTS & SDR-based access networks: cellular with D2D, ad hoc architecture; massive MIMO, TVWS, mmWave, microwave, LPWAN
Helikite
Ag vehicles, robots
Ag cameras, sensors, and actuators
Fiber SDNs
Edge and cloud compute resources & ARA integration with FABRIC, NSFCloud etc
Rural Settings
Wireless deployment in ag research & producer farms for crops and livestocks
Wireless deployment in rural schools and communities
Tools & Consortium
AraOS for safe, secure infrastructure virtualization & management
AraPortal & AraStore of user tools (e.g., measurement, emulation, data services, co-creation)
ARA Consortium
Modeling
Real-world wireless channel characterization: satellite, backhaul & access, mobile & static links
Real-world physical dynamics & mobility characterization of ag vehicles and robots
Architecture
Multi-modal, long-distance, high-throughput wireless backhauling: point-to-point & mesh
Cellular networking with massive MIMO and D2D links, ad hoc networking, and DTN
Mobile networking of ag vehicles and robots
Integrated wireless access and backhaul
Integrated wireless and fiber networking
Integrated wireless and fiber networking, and edge/cloud computing
Technology & Service
Ultra-reliable, low-latency communication (URLLC)
Massive MIMO, beamforming & beam tracking
Fixed and mobile mmWave networking
Massive machine-type-communication (mMTC)
Dynamic spectrum sharing
Seamless integration of licensed and unlicensed spectrum technologies (e.g., NB-IoT and Sigfox)
Green wireless networking
Network analytics
Application
AR/VR-based tele-operation of ag vehicles and robots; Real-time collaborative machine learning between ag vehicles and cloud
AR/VR-based crop phenotyping, animal health monitoring, and ag education

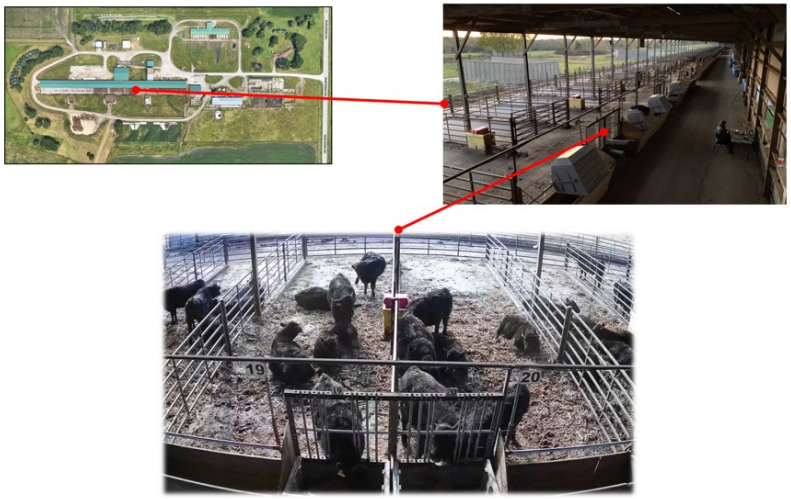
Exemplars: Wireless Research

- Long-distance, high-capacity wireless backhaul
- Advanced wireless access
  - mMIMO and mmWave in rural settings
  - mMTC, cMTC/URLLC
  - Cloud LPWAN for ag farms
- Spectrum innovation
- End-to-end cyberinfrastructure with wireless, fiber, edge & cloud

Exemplars: Applications Research

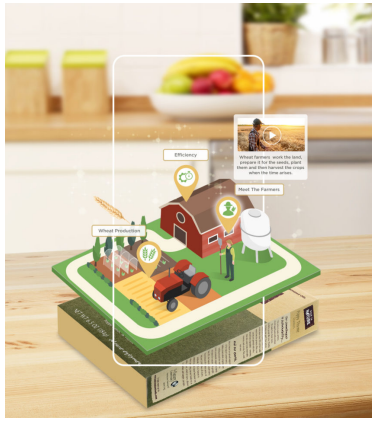


high-throughput phenotyping



precision livestock farming

agriculture automation

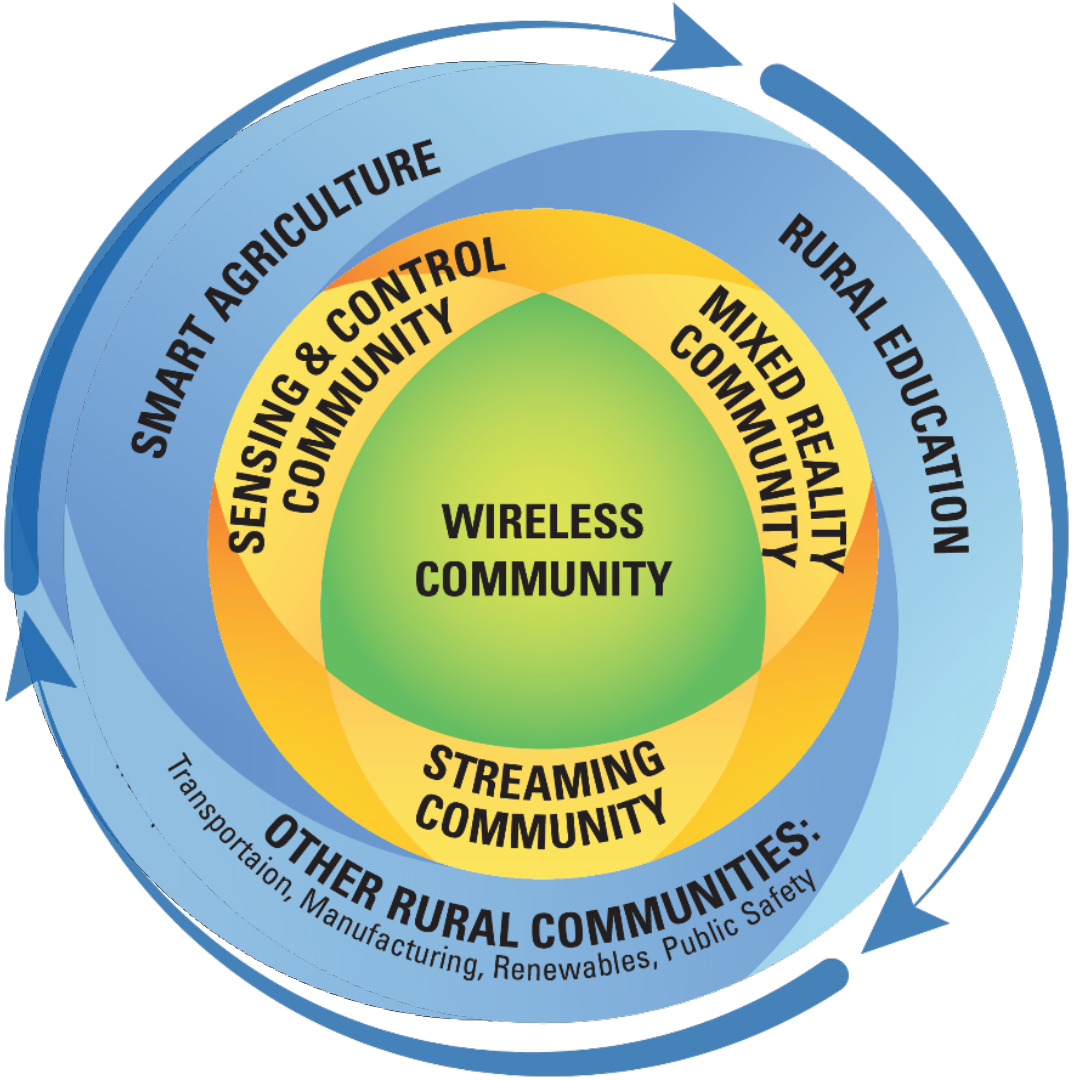


AR-based ag education
(Blippar, 2020)

ARA Making Rural Broadband as Affordable as Urban Broadband

- Factor of 10+ reduction in CapEx
- Demand incubation (e.g., pervasive precision ag deployment)
- Community-driven broadband operation model

Living Lab for Cross-Community Collaboration



Call for Participation

- ara-users Google group
  - online forum
  - mailing list
- General inquiry/suggestion: contact@arawireless.org

www.arawireless.org

Contact: Hongwei Zhang, hongwei@iastate.edu, +1 515 294 2143