Wireless Living Lab for Smart Agriculture and Connected Rural Communities

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Rural Communities & Agriculture: Challenges and Opportunities

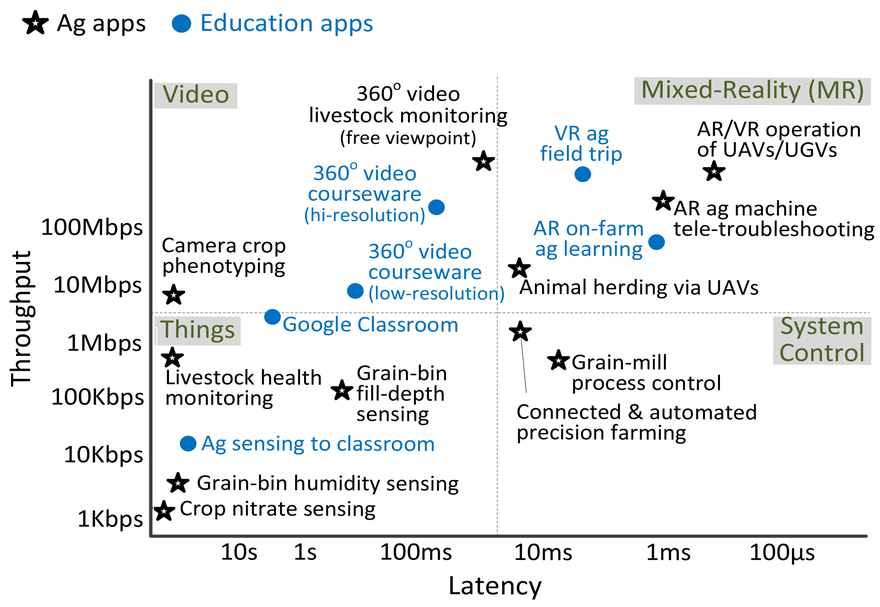
Rural US

- A foundation for society
  - ✓ Home to agriculture, manufacturing, renewable energy industries etc
  - ✓ Major source of food and energy
    - Agriculture & food sectors: $750+ billion contribution to annual GDP
- Challenges
  - ✓ Population shrinkage & labor shortage
  - ✓ Agriculture challenges
    - Feed growing population & demand while subject to climate changes
    - Address environmental impact and ensure sustainability: generate more output with less input (e.g., nitrogen, water)
  - ✓ Rural-urban education gap

Rural Connectivity

- As digital superhighway for rural prosperity
- Challenges
  - ✓ 39% rural US lacks broadband access
  - ✓ Most farms are not connected at all

Advanced Wireless Applications in Agriculture & Education

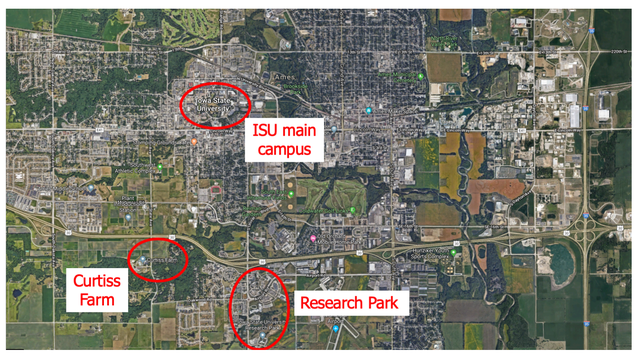


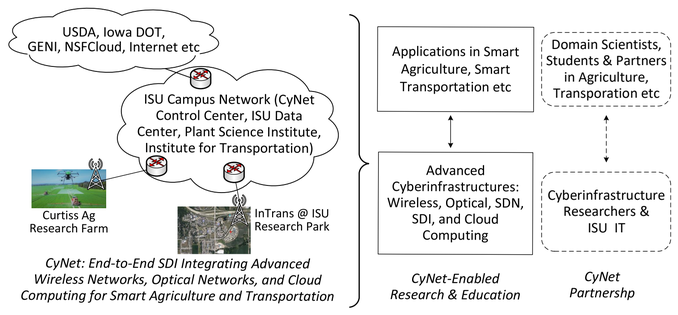
Rethinking Rural Connectivity & Wireless

- New perspectives
  - ✓ From fiber/copper to wireless
    - Wireless backbone networks
    - Wireless access networks
  - ✓ From rural communities for smart agriculture farms
- Enabling technologies & innovation paradigms
  - ✓ 5G & beyond
    - Massive & critical machine-type-communications: sensing, control, AR/VR etc
    - Massive MIMO, mmWave etc
  - ✓ CBRS, TVWS, dynamic spectrum, innovation zone etc
  - ✓ Open-innovation/open-source platforms for distributed innovation: OpenAirInterface, SDR, SDN etc
- Call to action
  - ✓ Public-private partnership: academia, industry, government, communities
  - ✓ Federal seed programs for innovation & capacity building in rural regions & communities

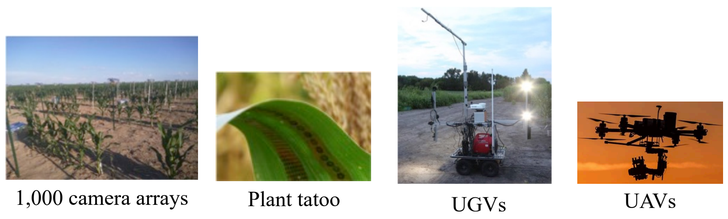
CyNet: Software-Defined Wireless Living Lab for Cross-Discipline, Cross-Domain Collaboration

Deployment & Partners

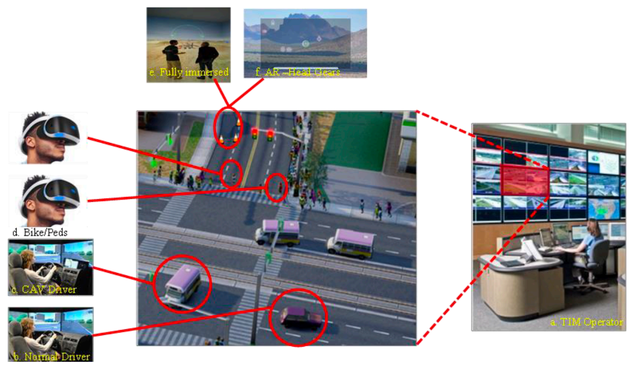




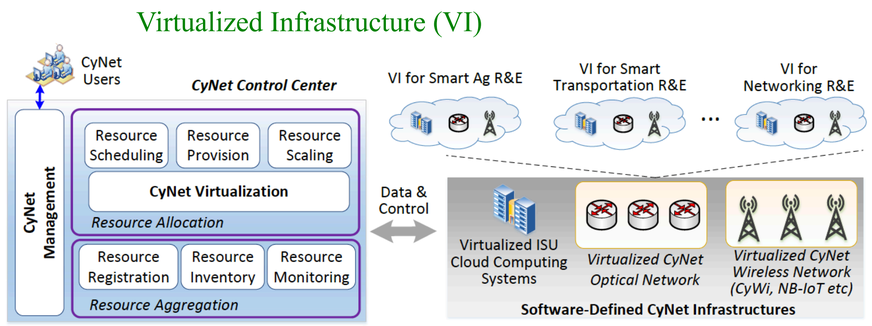
CyNet for Smart Agriculture



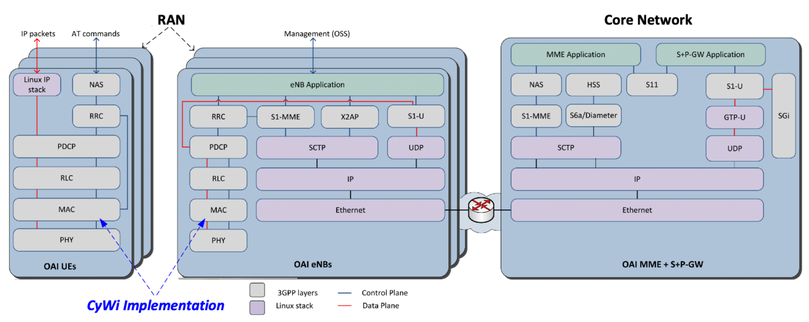
CyNet for AR/VR-based Multi-Mode CAT Emulation



Software-Defined CyNet



Open 5G/Wireless Innovation



Predictable, Reliable, Real-Time, High-Throughput (PRRT) Wireless Communication and Networking

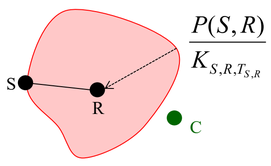
Predictable Wireless Interference Control as Fundamental Challenge

- Co-channel interference as a major obstacle for predictable reliability, real-time, and throughput in wireless networking
  - ✓ Reliability as low as ~30% in current wireless scheduling/MAC protocols, thus not suitable for real-time, safety-critical networked control
- Despite decades of research and practice, high-fidelity interference models that are suitable for distributed, field-deployable protocol design are still missing
  - Ratio-K model (i.e., protocol model) is local but not of high-fidelity
  - SINR model (i.e., physical model) is of high-fidelity but non-local

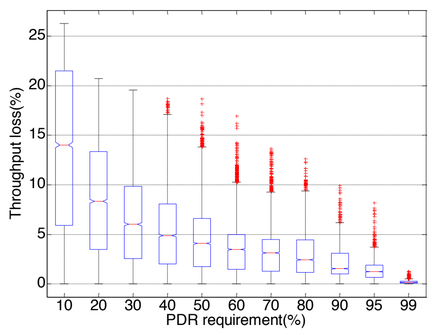
Physical-Ratio-K (PRK) Interference Model

- Key idea: use link reliability requirement as the basis of instantiating the ratio-K model
- Model: given a transmission from node S to node R, a concurrent transmitter C does not interfere with the reception at R iff.

$$P(C,R) \le \frac{P(S,R)}{K_{S,R,T_{S,R}}}$$

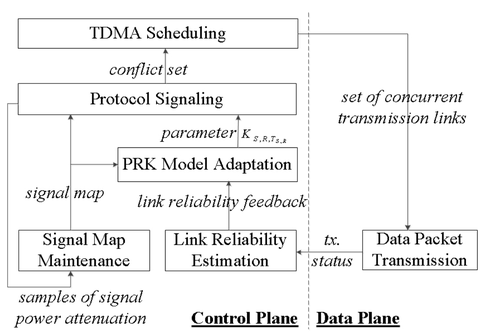


Optimality of PRK-Based Scheduling

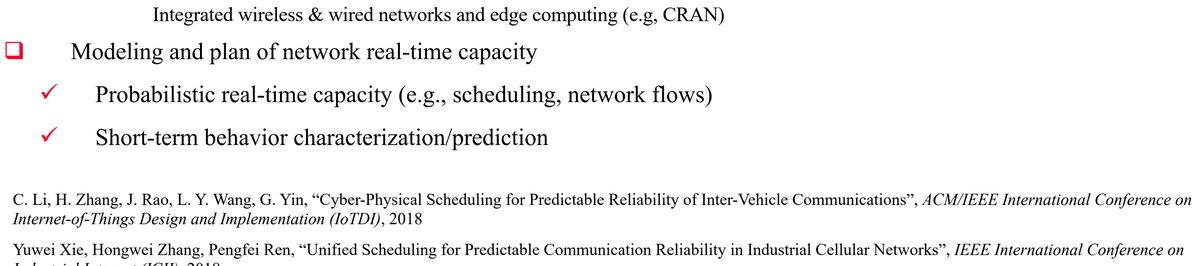


Throughput loss is small, and it tends to decrease as the PDR requirement increases

PRKS: PRK-based Scheduling



Predictable Link Reliability and High Throughput in PRKS



Transformative Impact on State of Art/Practice

From Predictable Interference Control to PRRT Wireless Communication & Networking

- Addressing dynamics & uncertainties of different spatiotemporal scales
  - ✓ Multi-scale network structures: Joint scheduling, channel hopping, power control, rate control, routing
  - ✓ Advanced communication techniques & architectures
    - Interference cancellation, anti-jamming, mmWave etc
    - Blurred boundary between cellular and ad hoc networks (e.g., D2D mode)
    - Integrated wireless & wired networks and edge computing (e.g, CRAN)
- Modeling and plan of network real-time capacity
  - ✓ Probabilistic real-time capacity (e.g., scheduling, network flows)
  - ✓ Short-term behavior characterization/prediction

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