Connected Infrastructure

Innovations in Education, Demonstration, and Applied Research (CIEDAR)

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Abstract

- Innovations in "Connected Infrastructure" are becoming increasingly important in the advent of "smart" everything .. smart cities, smart grid, smart transportation, smart buildings, et.al.
- Cross-domain issues in communications, technology standardization, federation of data, and interoperability clearly point towards a need for independent, large-scale testbed facilities.
- A similar need for closing gaps in workforce knowledge in-sync with the pace of technical evolution also leads toward facilities which enable just-in-time training and directed project evaluation.
- This presentation discusses an innovative approach to meshing research & development, large-scale demonstration & validation, and multi-disciplinary training in the context of an open consortium of industry, government, academia, and municipal actors.
- Specific projects are highlighted, and a "deep dive" into a novel approach to "DevSecOps" in the context of critical energy management is presented.
Stan McClellan

Professional Experience

● Co-Director, Connected Infrastructure Initiative (CIEDAR), Texas State University
● Professor, Ingram School of Engineering, Texas State University (2008 – Present)
● Director, Ingram School of Engineering, Texas State University (2013 – 2018)
● CTO & co-Founder, Power Tagging Technologies (2008-2010)

Publications & Activities

● Smart Cities in Application: Healthcare, Policy, and Innovation. Springer. 2019

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Andres Carvallo

Professional Experience

• Co-Director, Connected Infrastructure Initiative (CIEDAR), Texas State University
• Professor of Innovation and MARC Fellow, Texas State University (2019 – present)
• Executive Vice President of Energy Solutions & Chief Strategy Officer, Proximetry (2011 – 2013)
• Executive Vice President & Chief Strategy Officer, Grid Net (2010 – 2011)
• Chief Information Officer, Austin Energy (2003 – 2010)
• Chief Technology Officer, Pecan Street Project (2003 – 2010)

Publications & Activities

• The Advanced Smart Grid: Edge Power Driving Sustainability 2nd ed, Artech House, 2011.
• Smart Electric Power Alliance – Technology Board Advisor (2017 – present)
• Smart Grid Interoperability Panel (SGIP) – Board of Directors (2015 – 2017)
• Utility Telecom Council Smart Network Council – Board of Directors (2011 – 2014)
• Center for Commercialization of Electric Technologies – Board of Directors – 2006 – 2010
CIEDAR … Defined

- Consortium model for collaborative evaluation and prototyping at-scale
- Integrates industry partners, government entities, municipal entities, academic institutions
- A platform for targeted research, development, demonstration, and validation of “smart” tech

Andres Carvallo will provide more detail …
The Heart of the “Texas Innovation Corridor”
CIEDAR Vision

- The creation of multiple living labs within a smart neighborhood in partnership with industry to accelerate digitization and digitalization of industry.

- Vision: **Technology Enhanced Infrastructure**
Technology Enhanced Infrastructure
CIEDAR Mission

- The transdisciplinary study of technologies with application to infrastructure and lifecycle monitoring.
  - Activities: Validation, Evaluation, Development
  - Project teams: Civil, Electrical, Industrial, Mechanical engineers, Geographers, Mathematicians, Computer Scientists, Industrial Design and many others.
CIEDAR Overview

- Multi-Disciplinary Industry Research Center with 9 living labs
- Utilities, Cities, Structures & Buildings (IRL), Energy, Water & Wastewater, Mobility, Networks, Sensors, and Data/Software
- 92 faculty, 291 projects, 250 students, 32 laboratories, 7 centers
CIEDAR Locations

- Round Rock Campus
  - 100 acres

- Freeman Ranch
  - 4,100 acres

- Muller Ranch
  - 1,600 acres

- ALERRT Center
  - 20 acres

- San Marcos Campus
  - 500 acres

- STAR Park
  - 100 acres
Smart Networks Lab

- LTE, 5Ge, 5G, 6G, LPWA, LoRAWAN, LoRA, NB-IOT, IEC61850, Goose, DNP3, 6LowPAN, Extended Wi-Fi, WiSUN, Wirepass, RF-Mesh
- Power Management, GIS, Location Services, Applied AI/ML
- Sensors (wearables, embedded, nano, micro, water proof, printable, others)
- Data / Software (AI / ML, Blockchain, Databases, Cloud, Cybersecurity, Autonomous X, others)
Smart Buildings & Infrastructure Lab

- Steel, Aluminum, Wood, Composites, Concrete, Cement, Sand, Rocks, and others
- Roads, Sidewalks, Highways, Bridges, Tunnels, Overpasses, Trusses, Beams, Roofs, Columns, Doors, Windows, Escalators, and more
- Smart elevators, stairs, doors, windows, stairs, floors, roofs, ceilings, garage doors, locks, card readers, video cameras, motion detectors, and security alarms.
- Smart lighting, water systems, smoke detectors, vending machines, vehicle charging, ceilings, walls, roofs, and evacuation systems.
- Smart meters, broadband, Internet, energy systems, solar PVs, energy storage, smart appliances, electric vehicles.
- Smart HVACs, gas heating, chillers, boilers, pumps, thermostats, fans, air filters, humidifiers, fire alarms, and CO2 alarms.
Smart Energy Lab

- Smart Meters - Power and Gas (AMI: pre-pay, power factor, TOU pricing), Demand Response (DRMS for sensors)
- Smart Grid (SCADA/EMS, ADMS/DMS, OMS, GIS, VVO, VVC, CVR, FDIR, FLISR, Power Factor, Harmonics, Modulation, Power Electronics)
- Power, Heating and Cooling Microgrids (Home, Community, Campus)
- Energy NOC (Video Wall)

- Transmission and Distribution Gear (Transformers, Reclosures, Switches, Feeders, Tap Changers, Bushings, HV Wires, MV Wires, LV Wires, Cap Banks)
- Crews and Vehicle Management (GPS, WMS, AVL)
- Billing and Payments (CIS, MDM)
- Security (video, encryption, tunneling, NERC/CIP)
- Utility Scale Power Plants (CHP, Solar, Geothermal, GMS, SCADA/EMS, GIS, GPS)
Smart Utilities Lab


Smart Cities Lab


- Customer Emergency and Citizen Comments (911, 311)


- Police, Fire and EMS Vehicles (WMS, AVL, GPS), Body worn cameras (AVL, GPS), Public Safety NOC (Video Wall)
Smart Mobility Lab

- Roads, Sidewalks, Highways, Bridges, Tunnels, and Overpasses
- Connected Vehicles, Electric Vehicles, Charging Stations, Autonomous Vehicles, Control Software, Safety Systems
- Vehicle Tracking – Taxis, Ride-sharing, Commercial, Private, and Self-driving (GPS), Planes, Drones, Buses and Trains (GPS and Public DB), Car and Bike sharing (GPS), Bridges and Tunnels (GPS), Crews and Vehicle Management (WMS, AVL)
- Wi-Fi Customer Access at all Vehicles, Ticketing and Payments, Security (video, encryption, tunneling), Transportation NOC.
- AI / ML, Blockchain, Databases, Cloud, Cybersecurity, Autonomous X, others.
- Street Signage, Mapping Technologies, Voice Control, GIS, Location Services, Written Equations, Applied AI/ML, Smart Street Lights (AMI), Smart Traffic Lights (AMI), Smart Parking Meters (GPS)
Grid CPU

A “Deep Dive”
on a Specific CIEDAR Project
with Large-Scale Implications

Segments of this material derive from an invited presentation to
the SRC/DoE Workshop on ICT Hardware Enabled Security, August 25-27, 2020,
with collaborators Hongyu Wu – Kansas State Univ. and Erfan Ibrahim – Bit Bazaar, LLC
“Grid” vs. “Smart Grid”

• Today’s “Grid”
  - Embedded computing systems distributed throughout for telemetry and remote control (“SCADA”)
  - These systems are largely disconnected from the Internet via private networks (“air gap”)

• Tomorrow’s “Smart Grid”
  - Enhances these systems, connecting them together (“IIoT”)
  - Trend toward privately managed wireless continues, with interconnects
  - Virtually impossible to maintain “air gap” end-to-end
Technology / Network Context

• Abiding Issues
  - Software … fuggeddaboudit
  - Hardware … difficult to fix, broad-based effects (Spectre, IDS/IPS)

• Interesting Concepts
  - Statistically optimized CPU architecture based on workloads
    • Hennessy & Patterson … RISC vs. CISC
  - Lockstep & Redundancy: Parity between CPUs, modules, cores
    • ARM “TrustZone” – NXP “SecureElement” – Synopsys “DesignWare”
Security: Continuous Integration

• Integration
  - To address cyber-security issues in all network-connected devices, measures must be integrated into the technology stack, from top to bottom … not just via software or external devices (IDS/IPS)
  - Security (and compliance) must be integrated longitudinally throughout the development & deployment cycle … to mitigate system risk

• Lowest-level devices may benefit from “Analysis By Synthesis”
  - Consider RISC vs. CISC … static Analysis By Synthesis (sort of)
  - Consider adding telemetry … dynamic Analysis By Synthesis
IT Precedent: DevSecOps

- Building security into system development, from end to end
- Continuous and integrated, at every stage of the system life cycle
- Is an approach to “Analysis By Synthesis” for complex, networked systems with substantial software content

RedHat, “What is DevSecOps?”
https://www.redhat.com/en/topics/devops/what-is-devsecops
Proposal: Joint Optimization

- Control systems used in today’s “Smart Grid” are vulnerable
  - Large “threat surface” due to underlying, general-purpose CPUs
  - Systems not jointly optimized for cyber-resilience and critical use-cases
- Integrate DevSecOps with Machine Learning
  - We propose an approach which combines Machine Learning with telemetry to jointly and continuously optimize the CPU architecture
  - Includes critical use-case analysis, metrics for evolving / simulated threat vectors, and cost of upgrade vs. liability of compromise

“Dynamic Machine Architecture via Analysis By Synthesis”
Cloud-Based Re-Optimization

• Optimization
  - Analyze sequences of power-system operations ("SCADA") using ML techniques
  - Optimize the system response including extant and simulated threat vectors
  - Encode operating parameters in self-validating lists of context blocks
  - Cross-validate groups of context blocks with related use-case sequences

• Operation
  - “Meta-fetch” pre-validated context blocks enables application-level authentication
  - Cross-validation of blocks with actual use-case context before execution
  - Execute verified sequences of blocks, guaranteeing fidelity during disruptive events
Integrated Predictive Upgrade

Design Re-Optimization

Use-Case Enhancement

Cyber-Threat Mitigation

ROI Validation

ROI Failure
No Upgrade

ROI Success
Scheduled Upgrade

Telemetry Data

Initial Deployment

In Operation

Rate-Case Uses ROI Basis

Predictive Upgrade

Use-Case Enhancement

ROI Validation

Telemetry Data

ROI Failure
No Upgrade

ROI Success
Scheduled Upgrade

Telemetry Data

Initial Deployment

In Operation

Rate-Case Uses ROI Basis
Benefits

- Ongoing, joint optimization with known & simulated threat vectors
  - Design of primitive functional sequences for “fail-safe” operation
  - Addresses emerging / unknown cyber-threats

- Cloud-based design approach
  - Ongoing joint-optimization includes use-cases and evolving threat vectors
  - ML algorithms operate via telemetry from slices of deployed systems

- Mitigates threats for critical systems
  - Clearly-defined cost/benefit metric (“ROI” includes security metric)
  - Enables prioritizing costly upgrades of deployed or at-risk subsystems
Recap: CIEDAR Key Projects

- **Facilities**
  - Smart Building & Infrastructure Lab
  - Smart Public Safety mass shooting testbed
  - Workforce Housing competition & buildout
- **Energy**
  - 300-acre Solar PV Farm testbed, competition, & Smart Energy Lab
  - Digital Substation of the Future and Smart Utilities Lab
- **Drones & Transportation**
  - Power Line and Tower Inspection testbed
  - Package Delivery & People Transport testbed
  - 100-acre Smart Mobility Track and Smart Mobility Lab
- **Network Testbeds**
  - Private LTE/5G 900 MHz licensed
  - Wirepass & Wi-SUN 900 MHz unlicensed
  - LoRA WAN 2.4 GHz unlicensed

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### Connected Infrastructure, Education, Demonstration, and Applied Research

- **Smart Utilities**
  - Grid management, full monitoring, control, and management of all assets

- **Smart Buildings**
  - Positive energy buildings, embedded sensors throughout, BIM, BAS, BAM

- **Smart Energy**
  - Energy storage & batteries, electric vehicles, microgrids, micro generation

- **Smart Water/Wastewater**
  - Water & waste treatment, recycling, desalination, conservation, safety

- **Smart Cities**
  - Streetlights, traffic lights, public safety, parking, recycling, etc.

- **Smart Mobility**
  - Roads, bridges, tunnels, connected vehicles, autonomous vehicles

- **Networks**
  - 5G, 4G, LTE, IoT, LPWA, LoRaWAN, LoRa, 6lowPAN, Extended Wi-Fi

- **Sensors**
  - Wearables, printable, embedded, nano, micro, waterproof, ingestible, others

- **Data / Software**
  - AI, ML, Blockchain, Databases, Cloud, Cybersecurity, Autonomous X
Thank You!

More information on CIEDAR:

- https://hillviews.txstate.edu/issues/2020/bobcat-strong/project-ciedar.html
- https://www.marc.txstate.edu/CIEDAR.html
- https://vimeo.com/445306772