Integrating Communications through Software-Defined Radio

12 March 2014
WInnComm

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Caveats

- Presentation based on work funded by the U.S. Department of Justice (National Institute of Justice Award # 2010-IJ-CX-K023 to Engility Corporation for the Communications Center of Excellence)
- Opinions are our own and do not represent positions of the U.S. Department of Justice or Engility Corporation for attribution

What is the challenge?

- Law enforcement, corrections, and public safety do not have sufficient wireless communications capabilities to adequately execute all of their diverse and evolving missions
- “From the time of the Public Safety Wireless Advisory Committee's (PSWAC) Final Report of September 11, 1996, until the PSWAC Follow-Up: Assessment of Future Spectrum and Technology (AFST) (2010–2020) dated June 22nd 2012, public safety has received significant spectrum allocations. Yet the nature of public safety operations and the growing need to better manage day-to-day operations and response to large complex incidents still leave public safety short of spectrum in key areas.”

What are we trying to do?

- Provide law enforcement, corrections, and public safety personnel with tools to meet their needs
  - Working in conjunction with existing and evolving capabilities (e.g., FirstNet)
- Provide critical data based on scientific study to inform technology investment, procurement, and deployment decisions in support of those needs
- Leverage technology and standards to better manage spectrum-dependent resources
  - Evolve new communications paradigms

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New Transformational Ideas

- Leveraging multiple technologies from NIJ-funded efforts as well as commercial, defense, and other verticals that can provide "better" tools for managing communications resources such as spectrum ("better" means greater control, greater capability, faster decisions)
- Integrating, deploying, and evaluating these technologies to derive quantitative measures of impact on agency operations.
- Positioning ourselves to integrate additional technologies (DoD, DARPA, NSF)
- Positioning for the Auction proceeds

Recent NIJ Communications R&D Projects

- SDR/Cognitive radio technology
  - To provide waveform recognition, reconfiguration, and interoperability
- Cognitive control of reconfigurable antennas
  - For enhanced coverage, interference mitigation, and power management
- Channel bonding across heterogeneous networks
  - For enhanced spectrum capacity and management

Integration

- Goal: Integration of demonstrable versions of R&D projects
- Developing a consolidated research platform specification
  - Modular, standards-based, open source, semi-hardened
- Providing path for integrating other capabilities
- Looking to leverage defense and other R&D

Evolving Technologies for Public Safety Communications

NIJ Antenna Research

DOD-Unique Definition of R&D

Basic Research (6.1):	Applied Research(6.2):	Advanced Technology Development (6.3):	Demonstration and Validation (6.4):
Systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and/or observable facts without specific applications toward processes or products in mind.	Systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.	Includes all efforts that have moved into the development and integration of hardware for field experiments and tests.	Includes all efforts necessary to evaluate integrated technologies in as realistic an operating environment as possible to assess the performance or cost reduction potential of advanced technology

NIJ Cognitive Radio (CR) Technology Research

NIJ Software Defined Radio (SDR) Research

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Public Safety Communications Software Defined Radio (SDR)

- Single & multi-band radios now possible:
  - VHF-Lo (50MHz) & VHF (150 MHz) & UHF (450 MHz) & UHF 800MHz & UHF 700MHz…
- Flexible hardware & flexible software
  - SOFT KNOBS
  - Multiple air formats (waveforms)
  - Reconfigurable software and/or hardware
- Not paired to a single proprietary technology base
- Potential solution to many issues
  - Operability
  - Interoperability
  - Graceful upgrade
- BUT many antenna issues still unresolved…

Public Safety Communications Reconfigurable Antennas

- Recent NIJ funded research: Multi-band SDR technology
  - Address single-band antenna limitations
  - Ability to reconfigure antenna to match SDR-driven radio reconfiguration
  - Constrained by antenna physics
- Technical and regulatory challenges with public safety broadband
  - 4.9 GHz, unlicensed Wi-Fi, then 700 MHz NPSBN Broadband
- Reconfigurable antenna architecture
  - Resonance (band coverage)
  - Direction (beamforming/nulling)
  - Control Antenna Gain
- Hardware interface for antenna control
- LMR and/or Broadband
- Potential solution:
  - Resolve Single Band Antenna issues
  - Critical for multiband radio technology/applications
  - Increase radio performance, which we hypothesize will increase practitioners effectiveness (to be determined by technology operational evaluation)

Public Safety Communications Cognitive Radio

- Add a layer of intelligence to SDR
  - Software to control SDR via SOFT KNOBS
  - Learning/self-aware
  - Self-optimizing
- Add situational intelligence to radio ops.
  - Incident-specific intelligence
  - Role-based intelligence
  - Network optimization
- Application driven for specific goals
  - Address scenario-specific Interoperability/operability issues
  - Reconfigure communications capability as an incident evolves/ends

Public Safety Communications Cognitive Radio

- Ever-maturing SDR technology base
  - LMR and/or Broadband
  - Exploit evolving hardware capabilities
  - Increasingly flexible software configuration options
- Solve mission-specific communications issues for the end user
  - Automatically utilize multiple air formats (waveforms)
  - Find existing communications paths
  - Create new communications paths (dynamic spectrum access, LTE, TVWS, WiFi, Datacasting etc.)
  - Create ad-hoc networks
  - Optimize existing communications paths
  - Use resources in the most (mission-specific) efficient and/or cost-effective manner
  - Public Safety and/or commercial

Public Safety Communications Cognitive Radio

- Potential solution:
  - More effective utilization of available communications resources (14 June 2013 Presidential Memorandum)
    - Increase capacity
    - Allocate resources to get make sure critical information flows get highest priority
  - Increase practitioners' effectiveness (determined by NIJ Technology Operational Evaluation)
    - Measure impact on operational effectiveness (user and agency level)
    - E.g., Ability to reduce manpower required to configure radios/systems

Technology Integration Pilot Project (TIPP) Overview

- To address these these challenges, by leveraging evolving technologies from NIJ competitively funded R&D grants
- Most promising for integration:
  - Channel bonding across heterogeneous networks
    - For enhanced spectrum capacity and bandwidth management
  - Cognitive control of reconfigurable antennas
    - For enhanced coverage, improved spectrum efficiency, interference mitigation, and battery (power) management
    - Improved spectrum efficiency
  - Software defined/cognitive radios
    - SDR reconfiguration: waveform recognition & optimization for changing link characteristics
    - Provide spectrum efficiency and interoperability

Technology Integration Pilot Program (TIPP) Objectives/Design

- Objectives of integration
  - Move technology from proof-of-concept format to a platform suitable for technology operational evaluation
  - Investigate synergies across technologies
- Key design decision: define a hardware/software architecture (“integration platform”) for field demonstration of technologies. Hardware that is:
  - Modular (to allow flexibility to accommodate a variety of technologies)
  - Standards-based (to facilitate porting of functionality to the research platform)
  - Open source (to facilitate integration of future research and share technology)
  - Semi-hardened (to facilitate technology operational evaluation)

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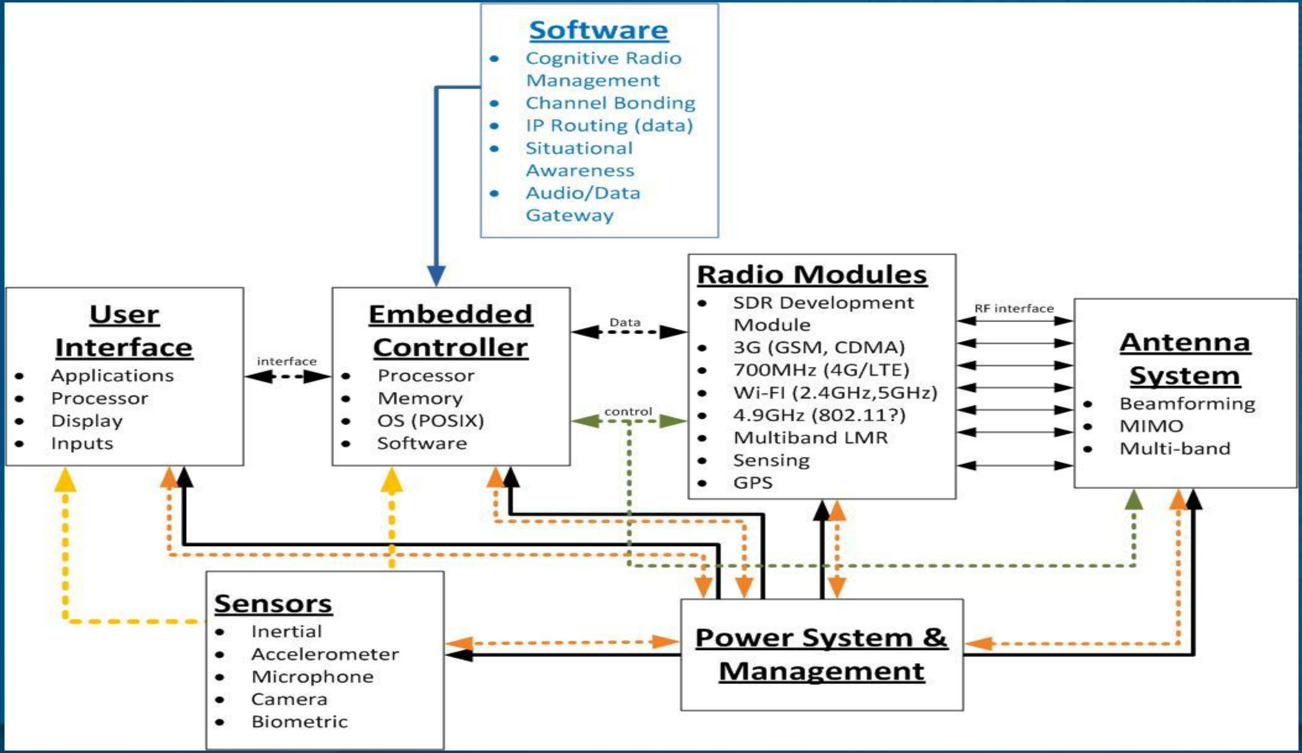
Functional Architecture



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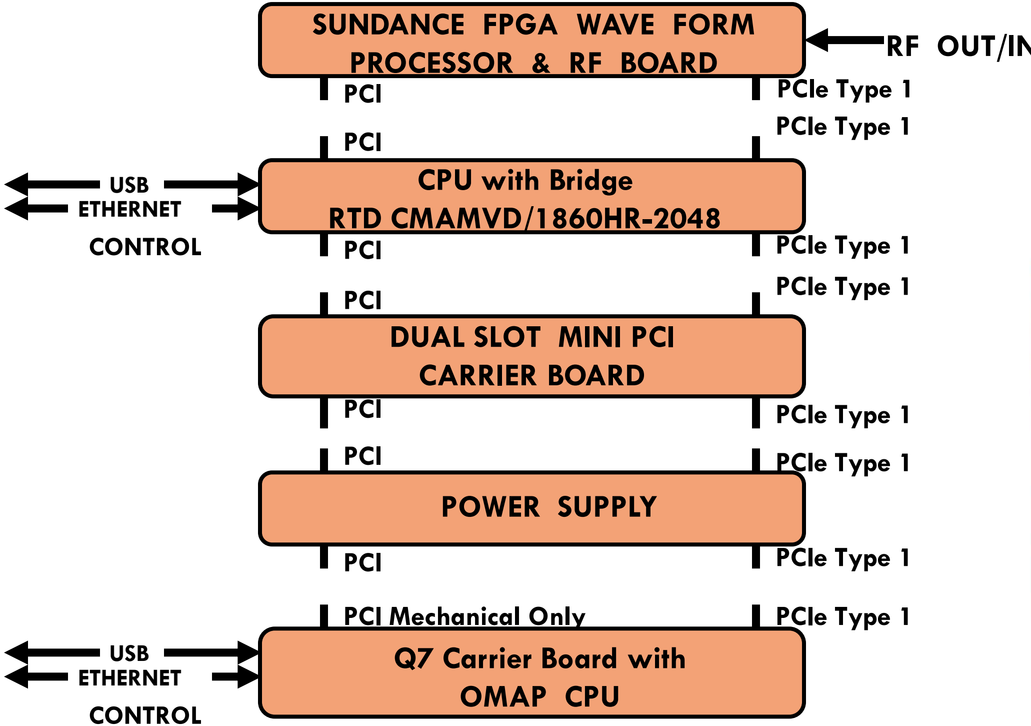
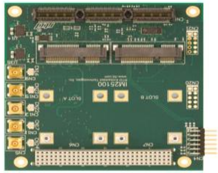
Integration Pilot— HW Architecture

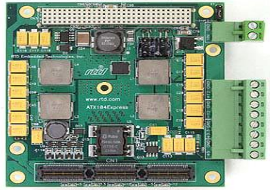
COE SDR PLATFORM BLOCK DIAGRAM

Revision A





MINI-PCI



STANDARDS

PCI/104

PCIe/104

MINI-PCI

USB

ETHERNET

KEY

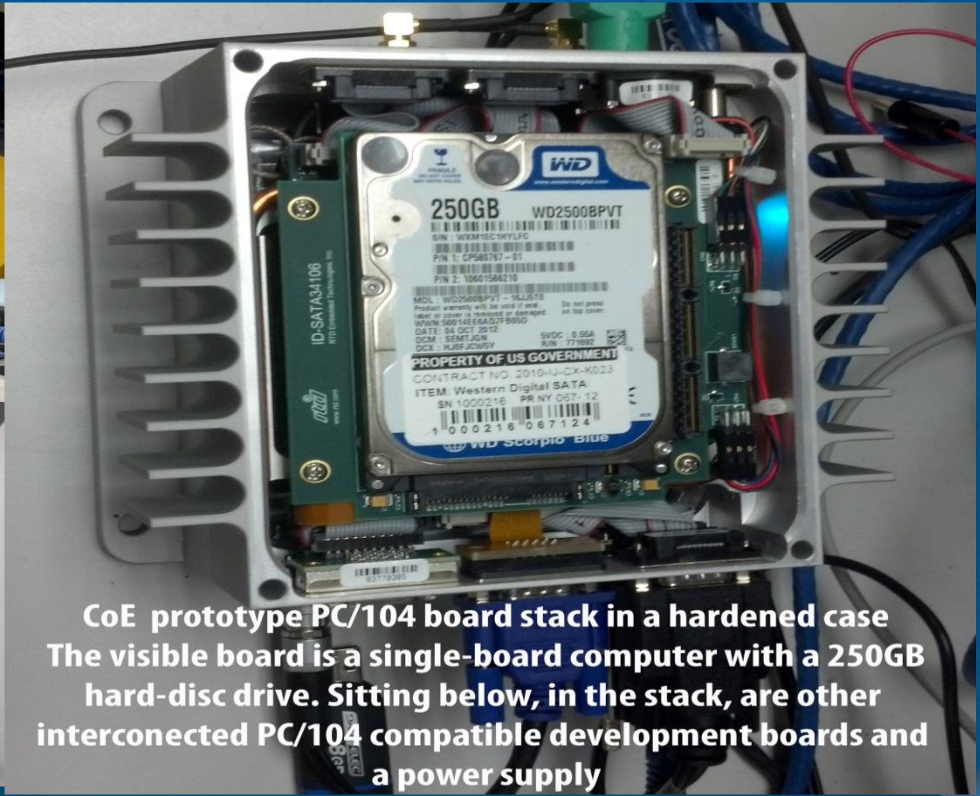
CUSTOM

COTS

Leonard D. Cope

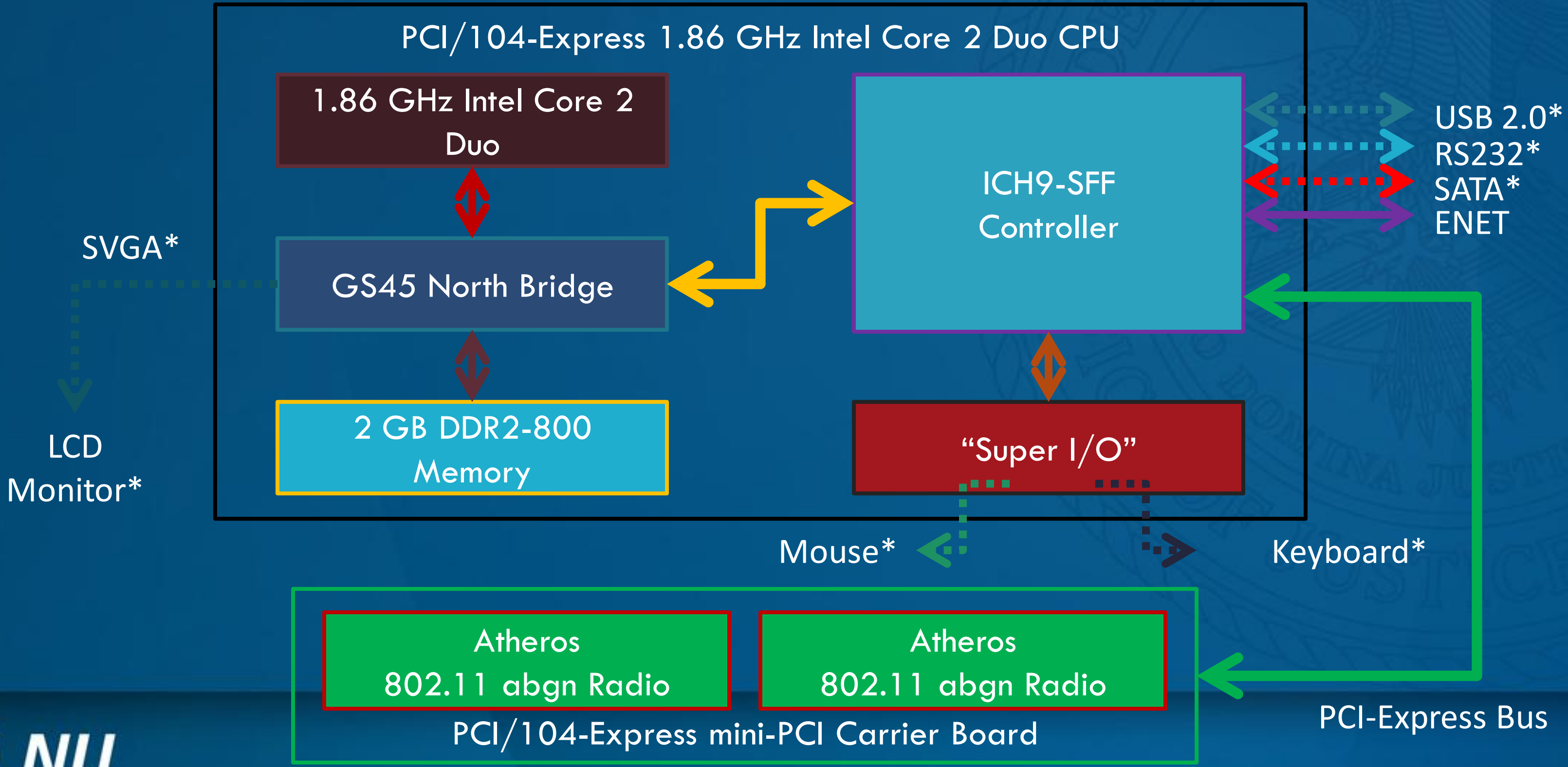
TIPP: Working Prototype

Detail View of Stacked Components



CoE prototype PC/104 board stack in a hardened case
The visible board is a single-board computer with a 250GB hard-disc drive. Sitting below, in the stack, are other interconected PC/104 compatible development boards and a power supply

Channel Bonding in the TIPP Architecture



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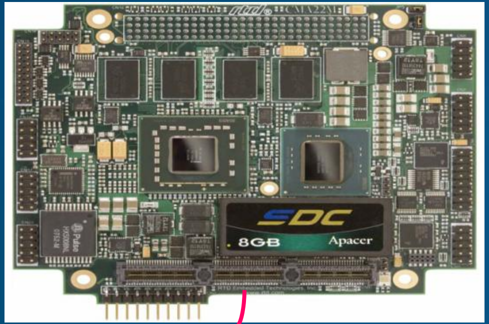
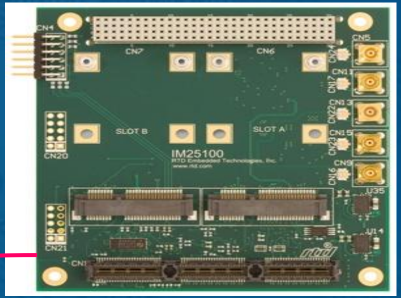
*Note: available for future expansion

Channel Bonding in the TIPP Architecture



x2



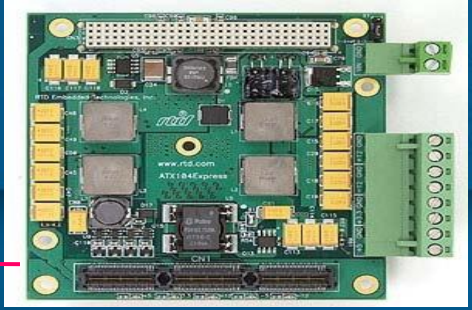
PCI/104-Express 1.86 GHz Core 2 Duo

PCIe | Mini-PCIe 802.11abgn Radio | PCI

PCI/104-Express mini-PCI Carrier Board

PCIe | PCI

PC/104-Express 88 Watt Power Supply



IDAN Configuration

Note: IDAN not shown for other modules

TIPP Integration: Channel Bonding Technology

- Original NIJ Research Awardee: Stevens Institute of Technology
- Today's Limitations:
  - Network connections & performance limited to single networks
- Technology Goals:
  - Allow resources from different networks; frequencies, channels to be combined into a single virtual channel
  - Cognitive aspects of radio technology that can sense RF interference then optimize transmissions to a different channel (frequency)
- Potential Applications :
  - Virtual channels with higher capacity and increased reliability,
  - Increased flexibility in regard to spectrum use
  - Ability to sense and avoid interference increasing robustness

TIPP Integration: Channel Bonding Technology

- COE has implemented capabilities from the Stevens Prototype
  - Implement Channel Bonding via 2.4GHz/5GHz "Point to point“ prototype on the NIJ TIPP platform (using 4.9 GHz)
  - Demonstrate Stevens Generation 1 channel Bonding Software
  - Demonstration of point-to-point IP Channel Bonding & Cognitive Mechanisms
  - Demonstrate “sense and avoid” mechanism: cognitive radio capabilities

TIPP Integration: NIJ Funded Smart Antenna Prototypes

- Original Research Awardee: University of California at Irvine
- Original Research Awardee: Utah State University
- Today:
  - Omni-directional antennas radiate in all directions (inefficient for some advanced applications)
- Long-Term COE Technology Goals:
  - Custom PC/104 compliant antenna architecture
  - Embedded CPU processor for SDR software interface
  - Software control of beam control (beamforming)
  - Future cognitive algorithms to increase antenna performance
- Potential Applications:
  - Communications links that are more robust with respect to interference
- Increase device energy efficiency via beamforming, in support of Dynamic Margin Scaling (DMS) research to extend device battery life

TIPP Integration: Smart Antenna Array

- COE Integration Goals: "Filling the gap"
- Optimized 4.9 GHz Public Safety Band Antenna Design
- Create software for basic antenna control & beamforming functionality
- Create & implement a custom PC/104 antenna control interface for both antenna & radio
- Demonstrate basic directional "beamforming antenna" control & functionality (via Butler array with 4 panels, 8 elements per panel)

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Questions???

Thank You.

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