JSC Low-Power, Low-Datarate Wireless Sensor Network Update

CCSDS Wireless Working Group
Spring 2011 Face-to-Face
Berlin, Germany

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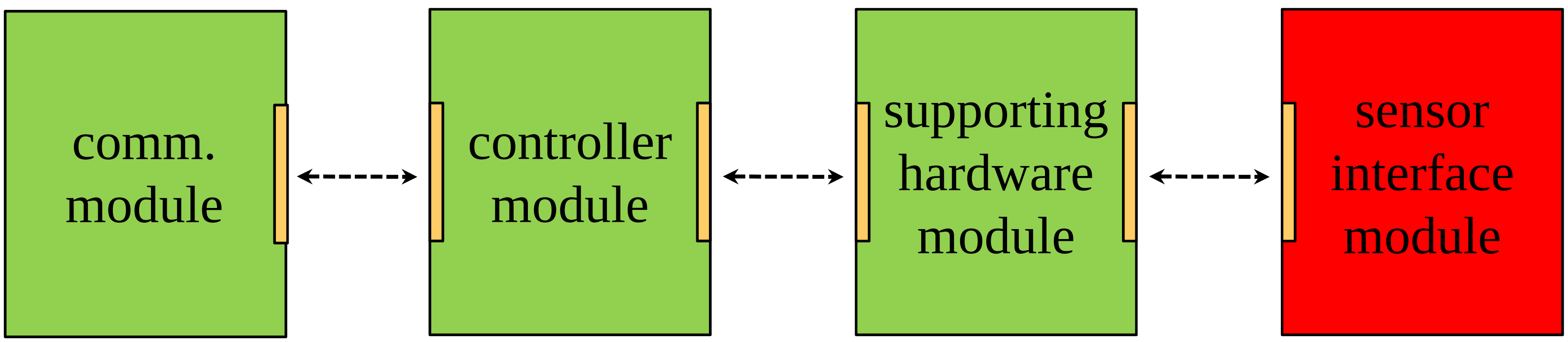
NASA-JSC/EV4

May 16, 2011

Agenda

- **Modular wireless instrumentation concept overview**
- **JSC WSN node v.1 review**
  - Desert RATS 2010 Habitat Demonstration Unit (HDU)
- **ISA100.11a and ZigBee performance comparison results**
  - JSC WSN node v.2, TI development hardware
- **Radiation testing results**
  - Nivis VN210 ISA100.11a radio, VR900 gateway
  - TI MSP430-F5438 microcontroller
- **JSC Modular Instrumentation v.1**
  - Nivis ISA100.11a radio
  - Desert RATS 2011 HDU
- **Forward Work**
  - Smart Sensor Inter-Agency Reference Testbench (SSIART)
  - 802.15.4a

JSC Modular Instrumentation Architecture



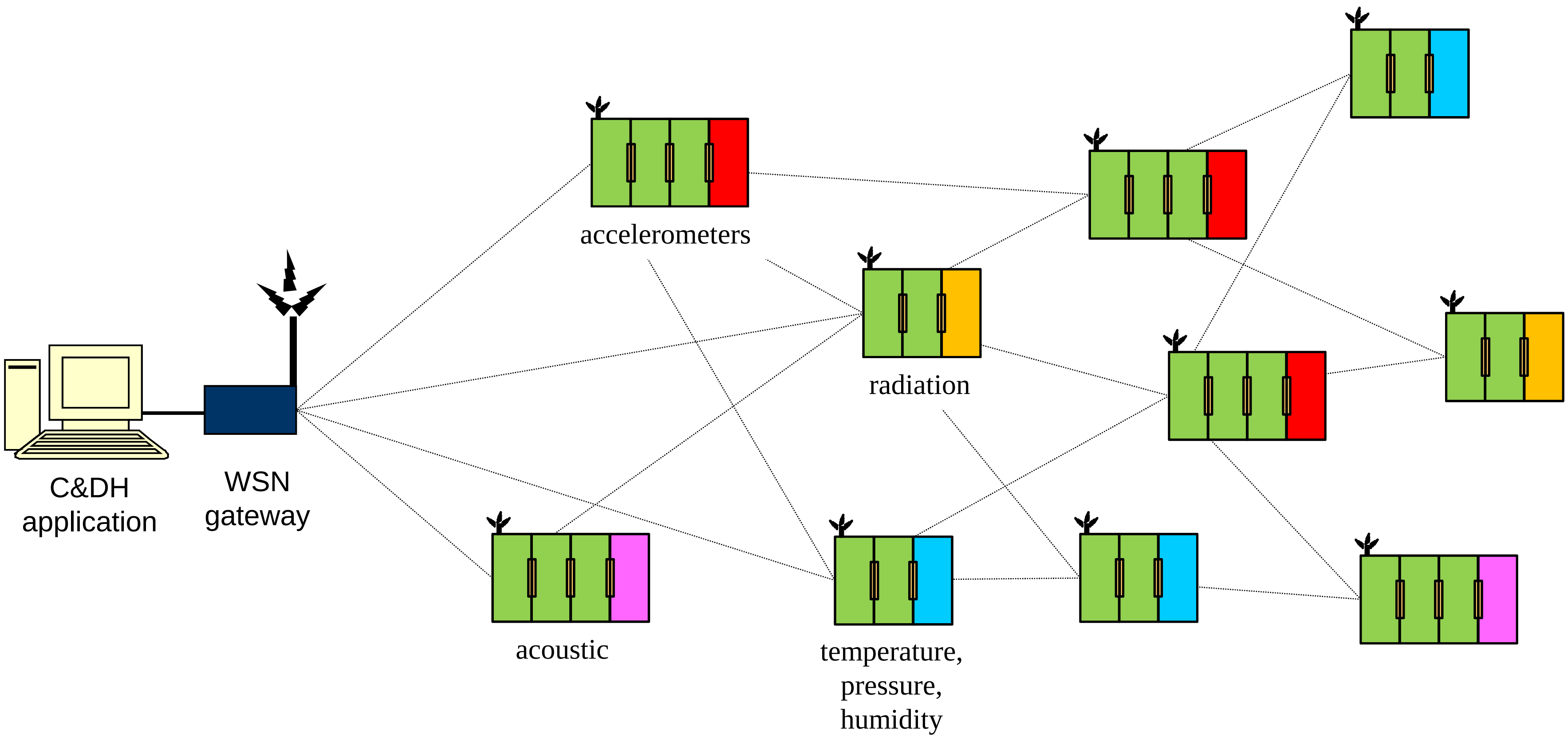
comm. module
- handles data transport to C&DH system
- forms common network with other nodes
- can be wired or wireless

controller module
- manages data acquisition
- processes sensed data as needed
- formats data for transport to C&DH

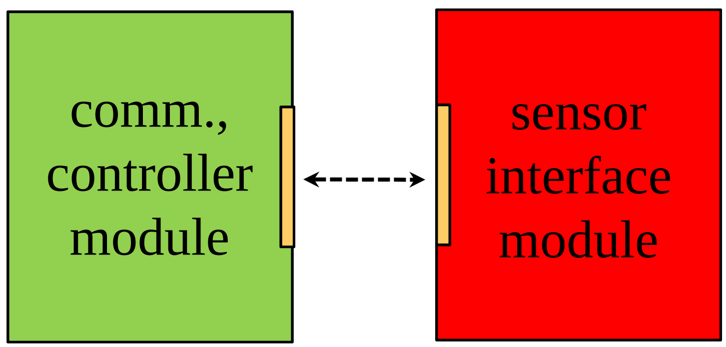
supporting hardware module
- provides added capability as needed
- e.g., volatile and non-volatile storage, high-speed A/D, DSP, …

sensor interface module
- provides application-specific sensors, sensor conditioning
- only custom-designed component

Modular, Standards-Based Wireless Sensor Network (WSN)



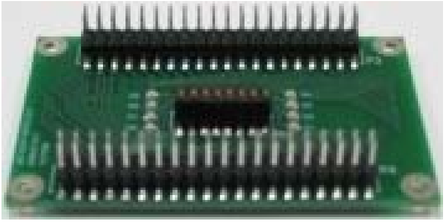
JSC WSN Node v.1, v.2 Architecture



JSC/EV WSN Node v.1

- **EV2/EV4–produced WSN node:**
  - – SB-WSN radio module
  - – TI MSP430 application processor
  - – fielded in Habitat Demonstration Unit at Desert RATS 2010
  - – forms basis for current EV2/EV4 modular instrumentation design (inc. advanced ISA100.11a WSN protocol) – to be demonstrated at Desert RATS 2011
- **Sensor cards:**

environmental
(light, 3-axis accel., temp.)



prototype/debug

HDU:
(10-channel 4-20 mA)

Habitat Demonstration Unit (HDU)

HDU participated in DesertRATS 2010 Exercises:

- 8 JSC nodes provided wireless instrumentation; 3 held in reserve
- Up to 10 channels of data gathered per node
  - temperature (LDC)
  - humidity (HDC)
  - differential pressure
- Requires coexistence with multiple wireless systems in an operational environment:
  - 802.11b, 802.11g
  - Tropos (extended-range .11n)
  - Bluetooth

ZigBee, ISA100 Performance Evaluation Hardware

- **JSC WSN node v. 2:**
  - Nivis VN210 radio, TI MSP430-F5438 microcontroller
- **TI MSP430 Experimenters Board:**
  - TI CC2530 radio (ZigBee Pro stack), TI MSP430-F5438 microcontroller
  - looks identical to custom ZigBee JSC node from application code point of view
  - low-cost stand-in

ZigBee

JSC WSN node v. 2 (ISA100)

ZigBee, ISA100 Performance Evaluation Methodology

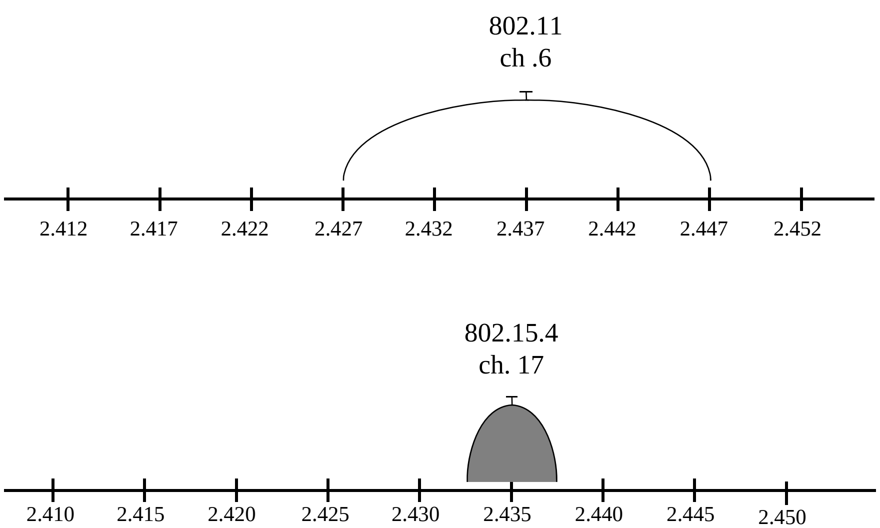
- **Primarily concerned with performance under RF interference conditions:**
  - measuring goodput – application level throughput

- **IEEE 802.11g router used as interference source:**
  - traffic generated between laptop (wireless to router) and workstation (wired to router) using Iperf
  - flows considered: 0 Mbps, 5 Mbps, 10 Mbps, 20 Mbps
  - also considered maximum single-flow (~ 30 Mbps)

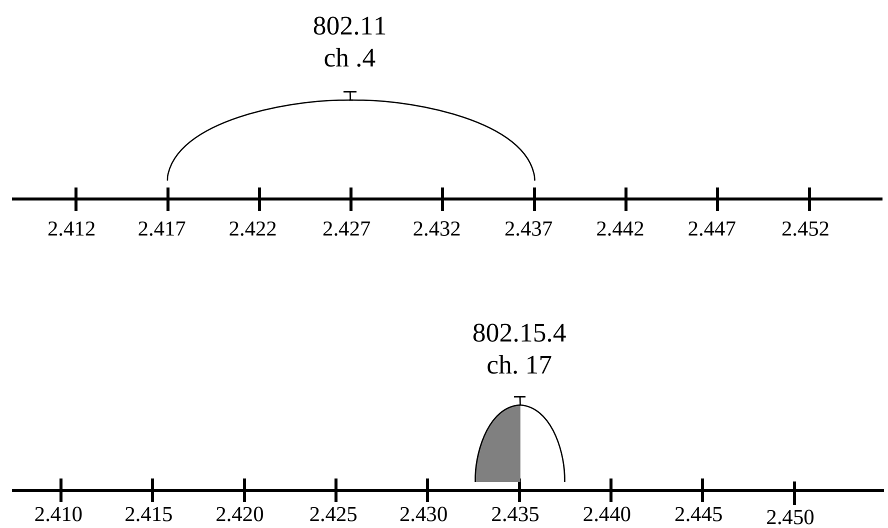
- **Maximum-length packets sent using each protocol at several periodicities:**
  - Packet lengths: 80B ZigBee, 76B ISA100.11a
  - Packet periodicities: 1 s/packet, 5 s/packet, 10 s/packet

ZigBee Performance Evaluation Setup

- **ZigBee nodes set to 802.15.4 channel 17 (2.435 GHz)**
- **802.11g set to generate two kinds interference:**
  - direct: 802.11 Ch. 6 (2.437 GHz)
  - sideband: 802.11 Ch. 4 (2.427 GHz)



direct interference



sideband interference

ZigBee Performance Evaluation Results

Interference Bandwidth:	Seconds Between packets	Test 1:	Test 2:	Test 3:	Average:	Std.Dev. Of Tests:
0	1	100.00			100.00	n/a
5	1	94.83	100.00	97.40	91.00	2.58
10	1	98.29	99.99	99.89	99.39	0.96
20	1	74.97	61.88	68.34	64.37	6.55
54	1	25.28	25.04	27.18	24.75	1.17
0	5	100.00			100.00	n/a
5	5	99.94	100.00	100.00	95.33	0.03
10	5	100.00	99.90	99.75	93.32	0.13
20	5	95.72	96.81	95.33	95.95	0.76
54	5	80.17	74.93	75.76	62.80	2.82
0	10	100.00	100.00	100.00	95.11	0.00
5	10	100.00	100.00	100.00	93.50	0.00
10	10	100.00	100.00	97.94	98.98	1.19
20	10	98.67	97.78	98.72	91.98	0.53
54	10	80.50	79.86	63.94	69.91	9.38

Direct Interference

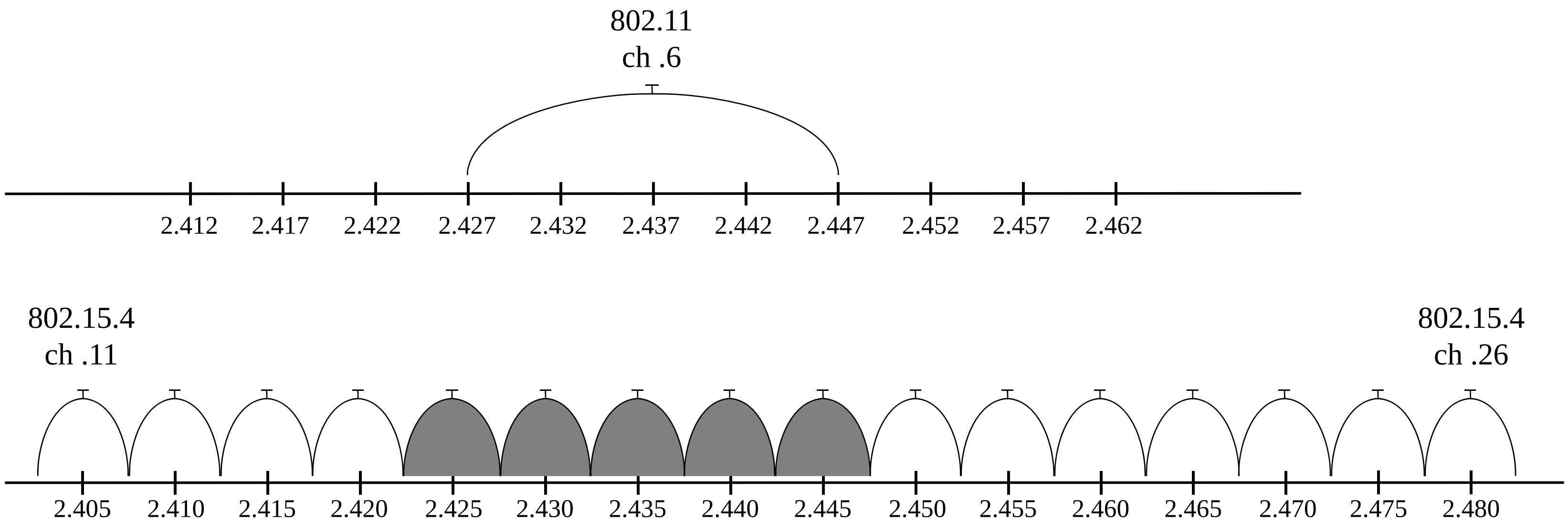
ZigBee Performance Evaluation Results

Interference Bandwidth:	Seconds Between packets	Test 1:	Test 2:	Test 3:	Average:	Std.Dev. Of Tests:
5	1	95.92	99.97	100.00	98.63	2.35
10	1	99.94	99.96	99.95	99.95	0.01
20	1	47.04	55.26	79.68	60.66	16.97
54	1	27.65	31.75	31.17	30.19	2.22
5	5	99.97	98.11	99.97	99.35	1.07
10	5	99.94	100.00	100.00	99.98	0.03
20	5	95.14	95.66	97.08	95.96	1.01
54	5	87.39	82.81	86.19	85.46	2.38
5	10	100.00	100.00	100.00	100.00	0.00
10	10	100.00	99.89	100.00	99.96	0.06
20	10	98.28	98.89	98.89	98.68	0.35
54	10	85.89	89.17	89.33	88.13	1.94

Sideband Interference

ISA100 Performance Evaluation Setup

- **ISA100 nodes use all 16 available 802.15.4 channels**
- **802.11g set to Ch. 6 (2.437 GHz)**

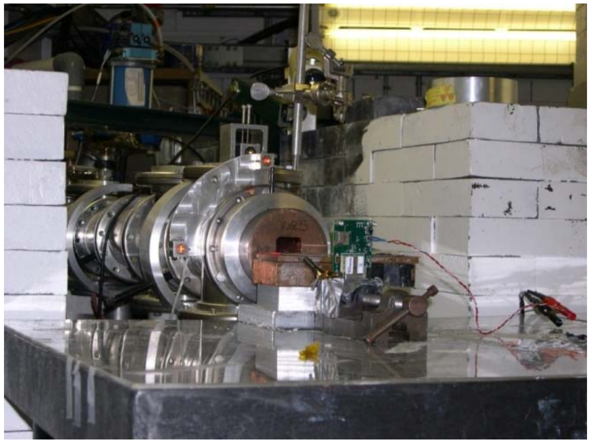


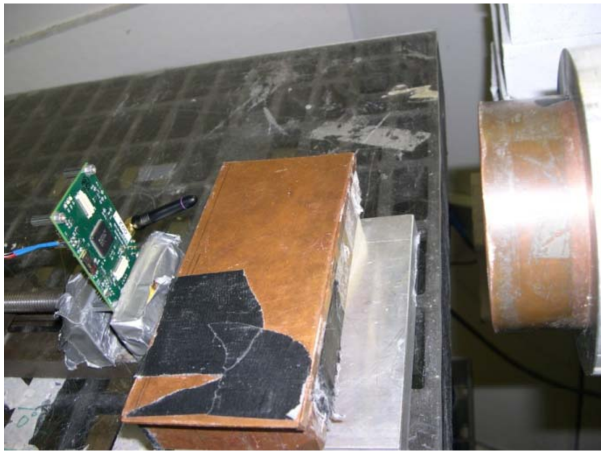
ISA100 Performance Evaluation Results

Interference Bandwidth:	Seconds Between packets	Test 1:	Test 2:	Test 3:	Average:	Std.Dev. Of Tests:
0	1	TBD	TBD	TBD	TBD	TBD
5	1	TBD	TBD	TBD	TBD	TBD
10	1	TBD	TBD	TBD	TBD	TBD
20	1	TBD	TBD	TBD	TBD	TBD
54	1	TBD	TBD	TBD	TBD	TBD
0	5	TBD	TBD	TBD	TBD	TBD
5	5	TBD	TBD	TBD	TBD	TBD
10	5	TBD	TBD	TBD	TBD	TBD
20	5	TBD	TBD	TBD	TBD	TBD
54	5	TBD	TBD	TBD	TBD	TBD
0	10	TBD	TBD	TBD	TBD	TBD
5	10	TBD	TBD	TBD	TBD	TBD
10	10	TBD	TBD	TBD	TBD	TBD
20	10	TBD	TBD	TBD	TBD	TBD
54	10	TBD	TBD	TBD	TBD	TBD

Nivis VN210, TI MSP430 Radiation Test

- **JSC WSN node v.2 and gateway tested at Indiana University Cyclotron Facility on 2/20/2011**
- **~ 200 mega-electron-volt (MeV) proton beam used**
- **Each beam position exposed to minimum fluence of $1e^{10}$ protons/cm^2 (600 rads)**
- **Each test run continued until an anomalous event was detected or the total $1e^{10}$ protons/cm^2 fluence reached**

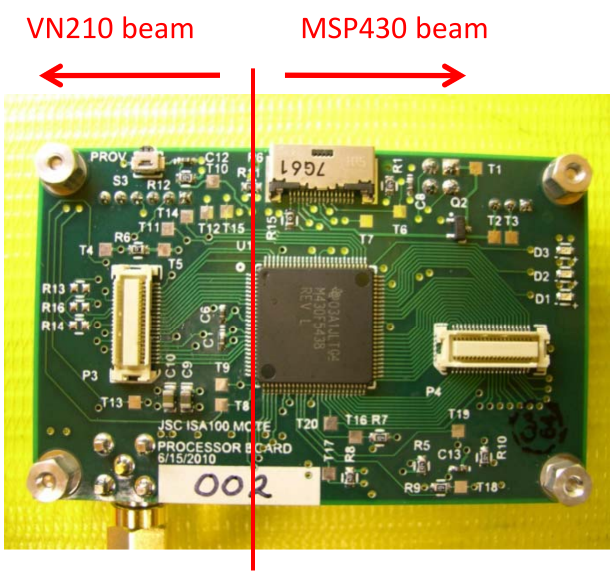




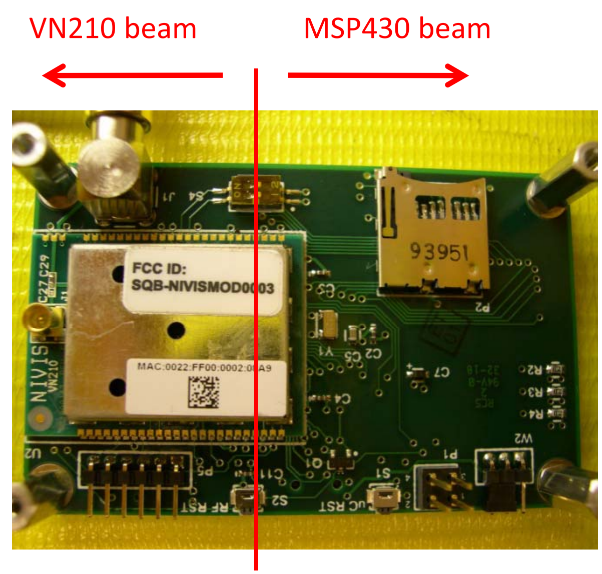
WSN node in beam

Nivis VN210, TI MSP430 Radiation Test

- **WSN node beam shielded to expose VN210, MSP430 separately**
- **MSP430 mean time between failure (MTBF) calculated at 596 days**
- **VN210 MTBF calculated at 86.3 days**
- **WSN node MTBF calculated at 75.4 days**



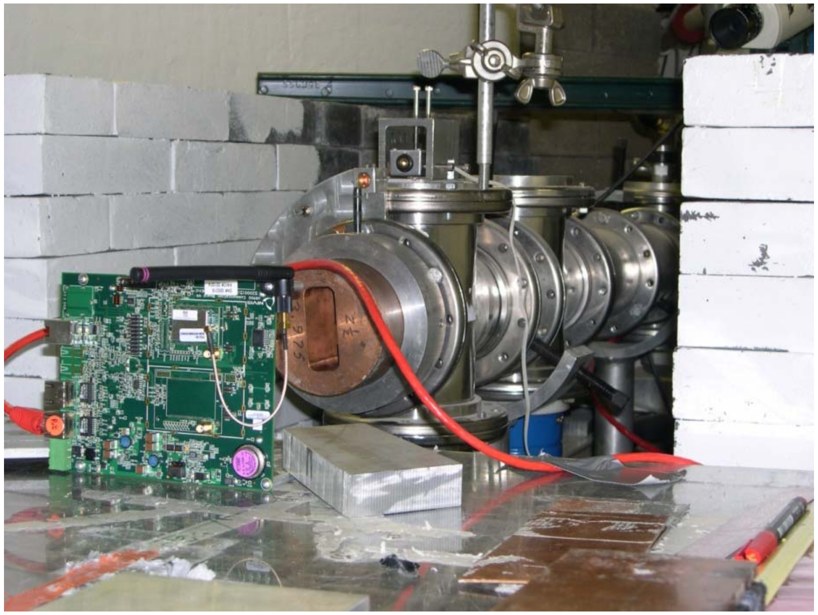
beam positioning (top view)



beam positioning (bottom view)

Nivis VR900 Radiation Test

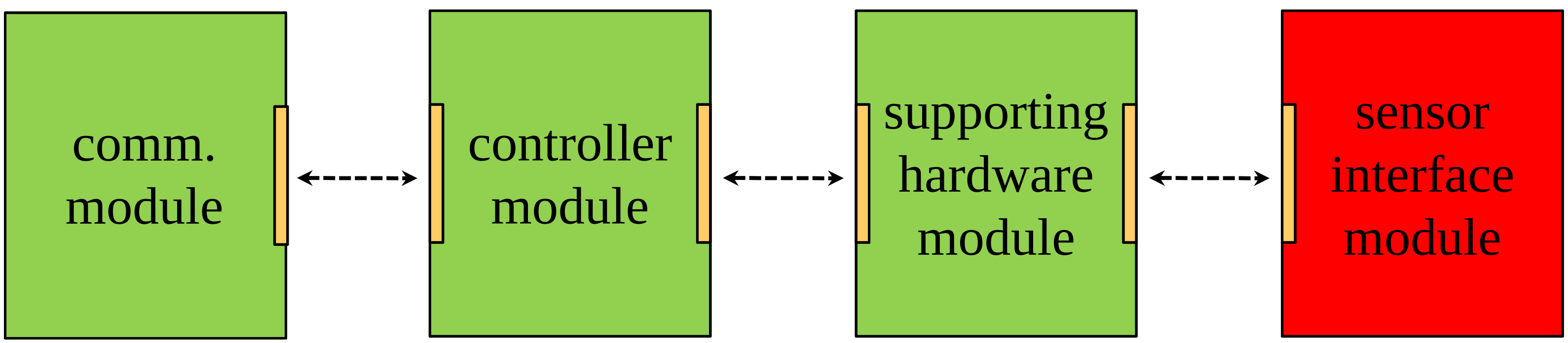
- **WSN node beam exposed VN210 radio (top) and FreeScale ColdFire processor board (bottom) in single beam**
- **VR900 mean time between failure (MTBF) calculated at 49.9 days**



VR900 in beam

JSC Modular Instrumentation, v. 1

- **WSN effort migrating to full modular instrumentation program**
- **Goal: stock of components than that can complete 80% of any distributed measurement task with 20% customization work**
- **Communication can be wired or wireless**
- **Provides platform for laboratory development of new radio platforms with path for quick infusion into field applications**



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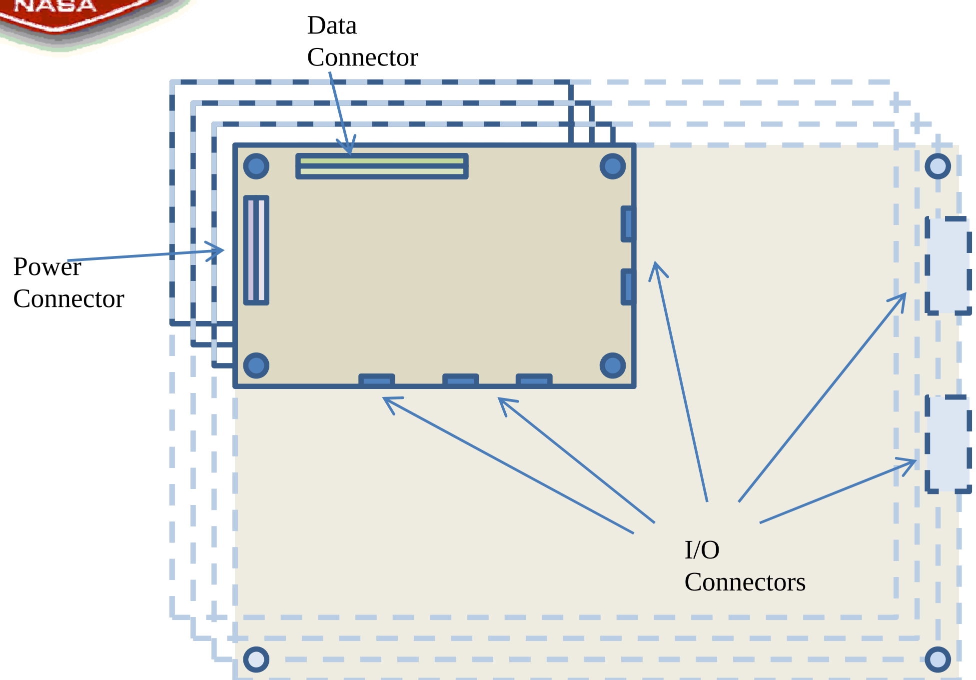
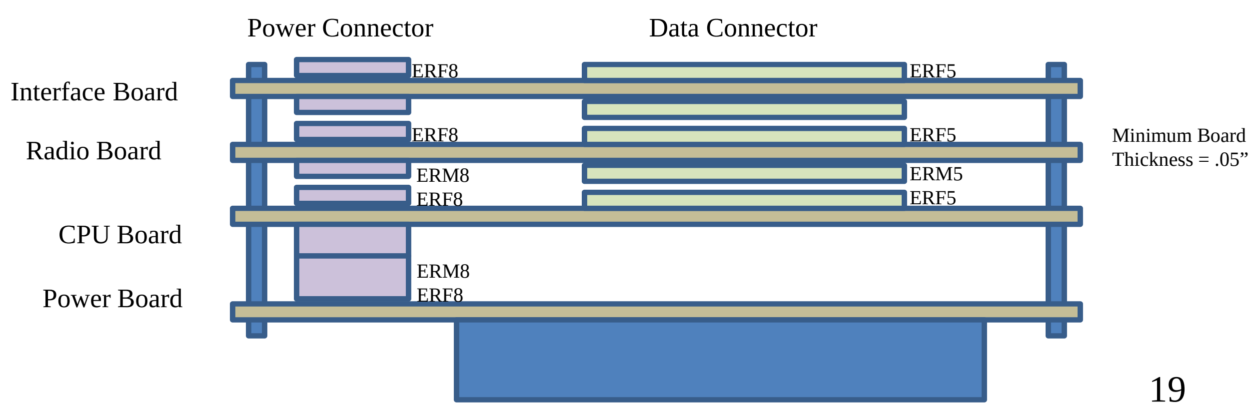
Modular Instrumentation Stack



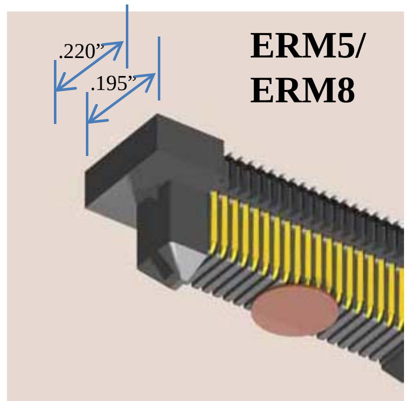


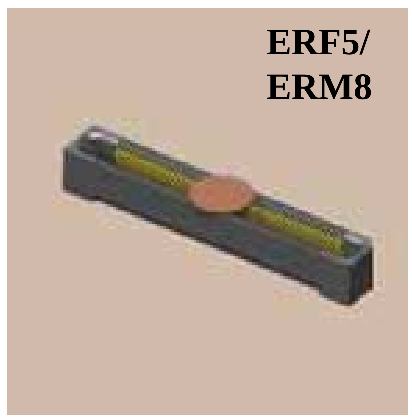
Power, Data Connector Details

Digital Ground (11pins)
Analog Ground (4pins)
+/- 12V (2pins)
+ 5V digital (3pins)
+/- 5V analog (2pins)
+ 3.3V or 3.0V (4pins)
+ 2.5V (4pins)
Reset (1 pin)
Power_good (1pin)
Spare (8pins)

40 pins total = .866” long (ERM8)

80
User defined
Pins = 1.056” long (ERM5)



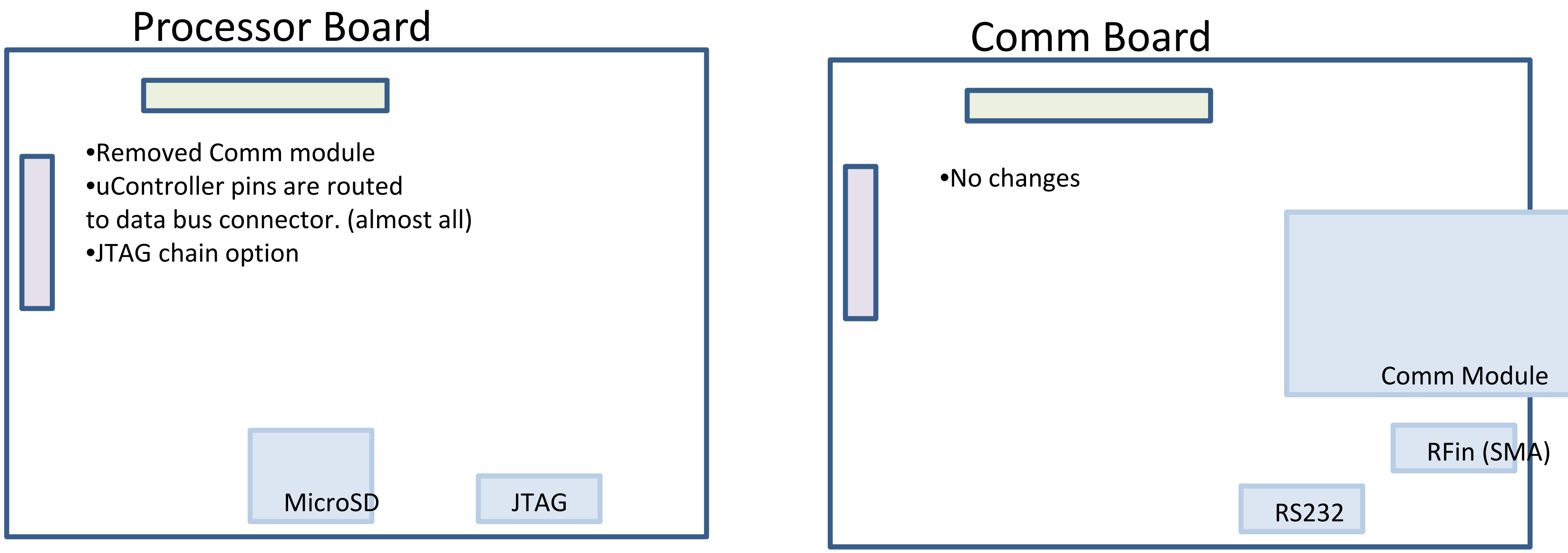


SAMTEC’s Rugged High Speed Socket/Header:
EREM8/ERF8 (for Power Connector)
SMT (.0315” pitch)
2.1A @ 85 C
ERM5/ERF5 (for Data Connector)
SMT (0.0197” pitch)
1.9A @ 80 C ambient
194VAC rated

Mated Height: (Power Connector)			
ERF8 LEAD STYLE	**ERM8 LEAD STYLE**		
	–02.0	**–04.0**	**–05.0**
–05.0 **–07.0**	**(7,00) .276** **(9,00) .354**	**NA** **NA**	**(10,00) .394** **(12,00) .472**

Mated Height: (Data Connector)			
ERF5 LEAD STYLE	**ERM5 LEAD STYLE**		
	–02.0	**–04.0**	**–05.0**
–05.0 **–07.0**	**(7,00) .276** **(9,00) .354**	(9,00) .354 (11,00) .433	**(10,00) .394** **(12,00) .472**

Modular Instrumentation Components



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Modular Instrumentation Components

Battery Power Board

- Battery input only (5Vdc wall input possible)
- 1.8V to 8V input Boost converter to 3.0V out
- Low power (300mA max)
- Vtest (1/4 of Vbatt) on the powerbus connector
- Low Battery Out (LBO) on the powerbus connector
- Isolated power and ground by default
- Power On switch
- Voltages on the powerbus:
    - Vbatt, 3.0Vdc, GND
    - 3.0Vdca, AGND
- Single point connection b/ AGND and GND

Battery (two AA's)

5VDC Wall Jack

28V Power Board (HDU)

- 28Vdc input or >9Vdc wall input possible
- Isolated DC to DC converter for 9-36V input
- 9-36Vdc input converted to 15Vdc out
- 15Vdc to be used on sensors
- 15Vdc is converted to 5Vdc out
- 5Vdc is converted to 3.0Vdc out
- Vtest (1/4 of 5Vdc) on the powerbus connector
- Low Battery Out (LBO) on the powerbus connector
- Power On Switch
- Total 3-stage converters
- Voltages on the powerbus:
    - 28Vdc (or Vwall), xGND
    - 15Vdc, AGND, 3.0Vdca
    - 5Vdc, 3.0Vdc, GND
- Single point connection b/ AGND and GND

28Vin

>9VDC Wall Jack

If this power board is used, other than processor board, what other boards will be serviced by this power supply? What is the power requirement?

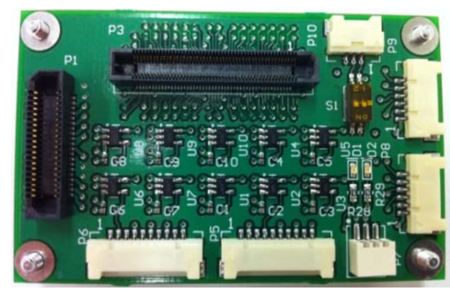
Mounting holes are tied to a thermal plane (if existing), **not** Grounded.

Modular Instrumentation v. 1 Prototype Components

processor board

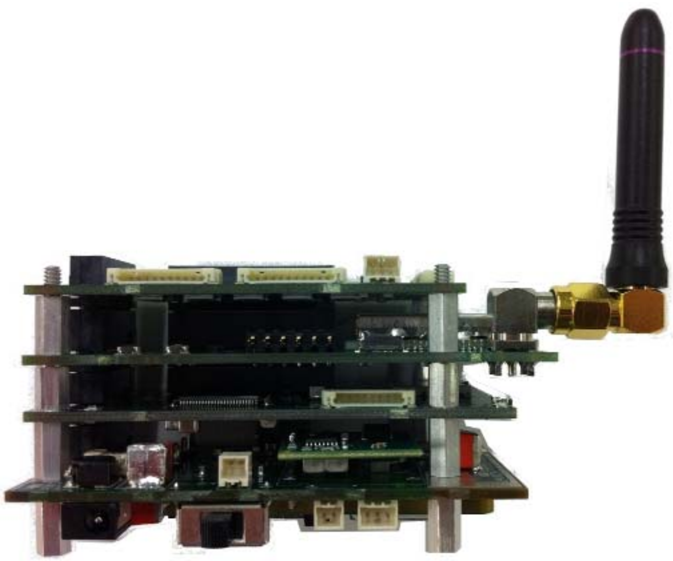
ISA100.11a comm. board

28V power board

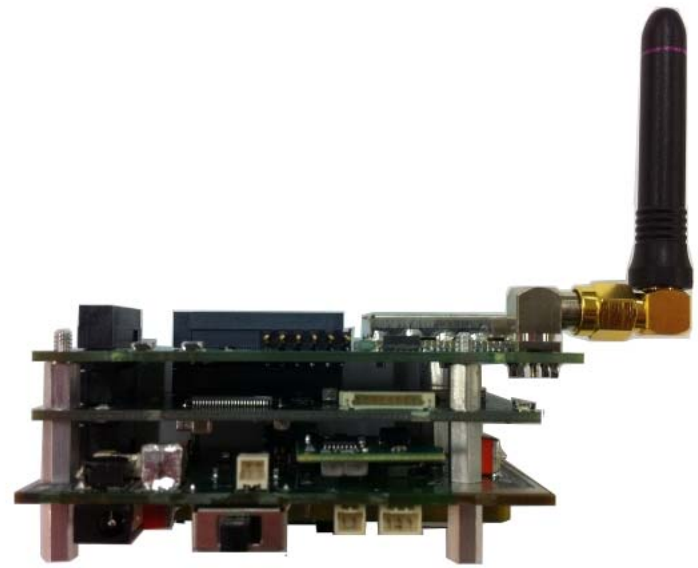


4-20mA current loop sensor board

Modular Instrumentation (v. 1)



4 board stack
(inc. sensors)



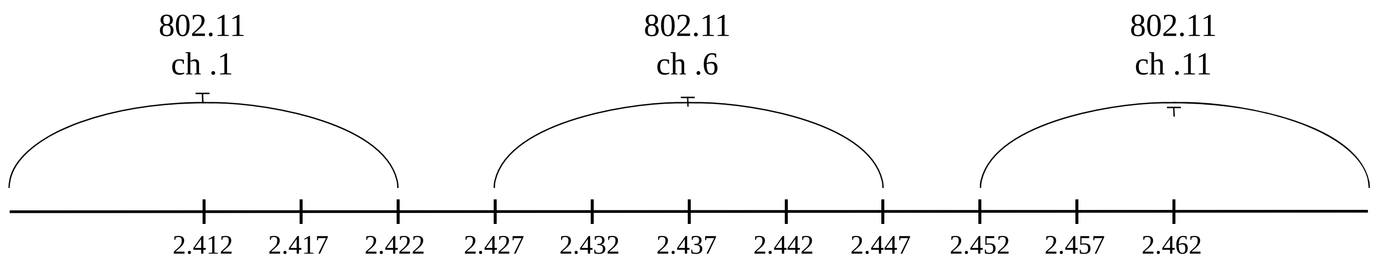
3 board stack

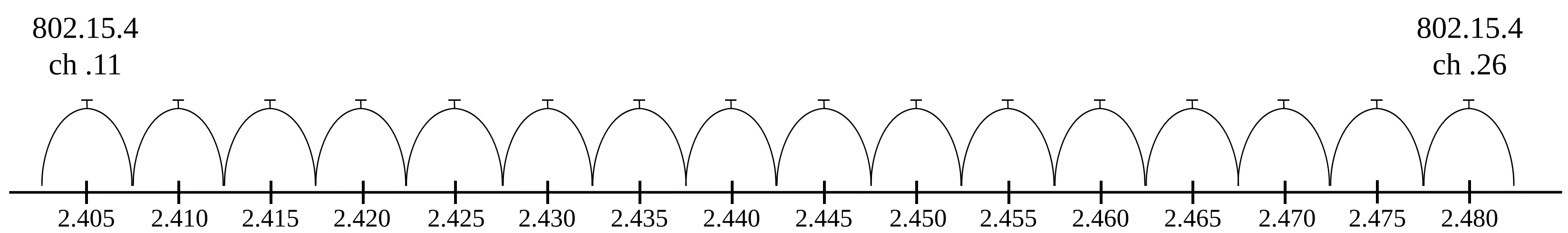
Forward Work

- **Complete ISA100.11a vs. ZigBee reliability study:**
  - develop 802.15.4/ZigBee modular radio component?
- **Extend ISA100.11a support to include full range of supported modes**
  - block-transfer at ~ 40 kbps
- **Investigate 802.15.4a capabilities with modular comm. board**
  - how to test/chracterize/compare?
- **Explore supporting SSIART with modular instrumentation hardaware**
  - what needs to change for v. 2 to make the toolkit more SSIART-like? what needs to stay the same?

Backup

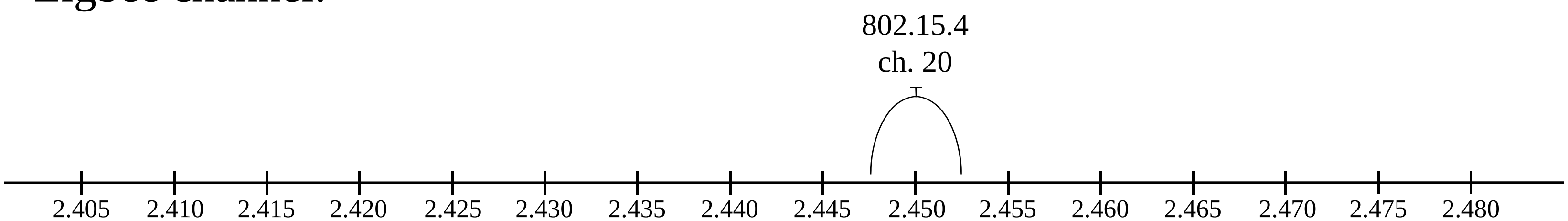
802.15.4 / 802.11 Coexistence



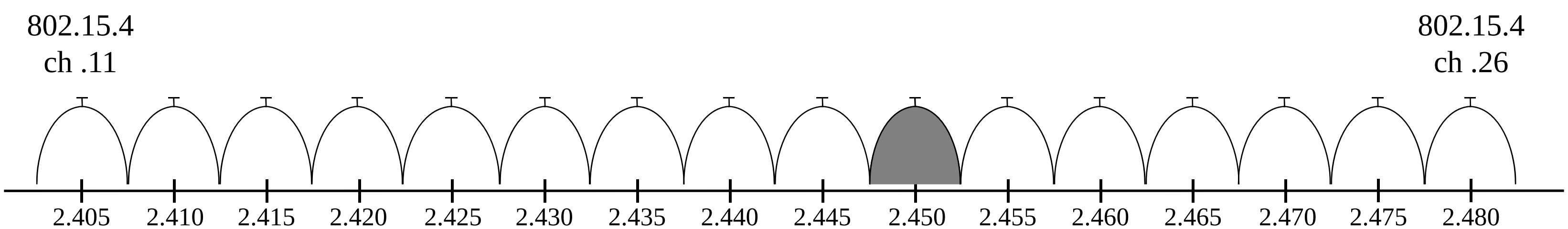


ISA100.11a/Zigbee Coexistence

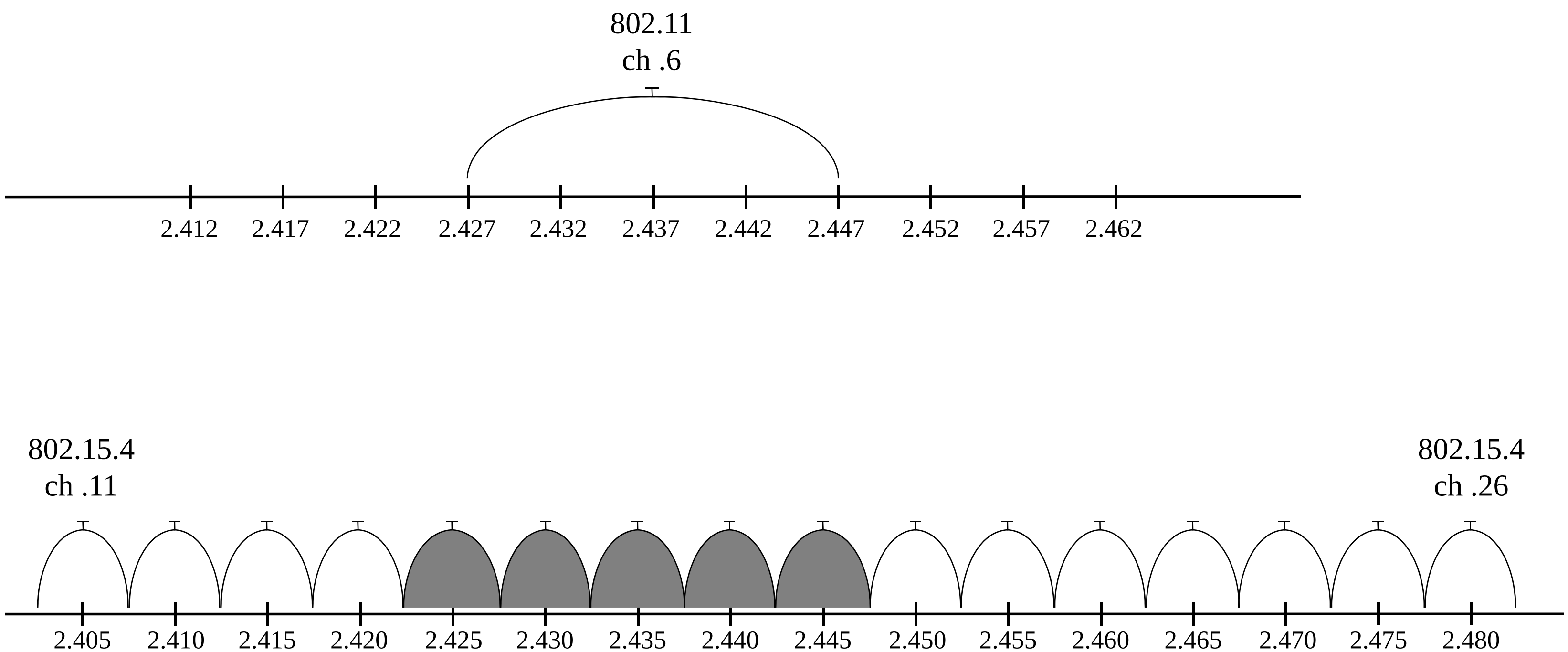
Zigbee channel:



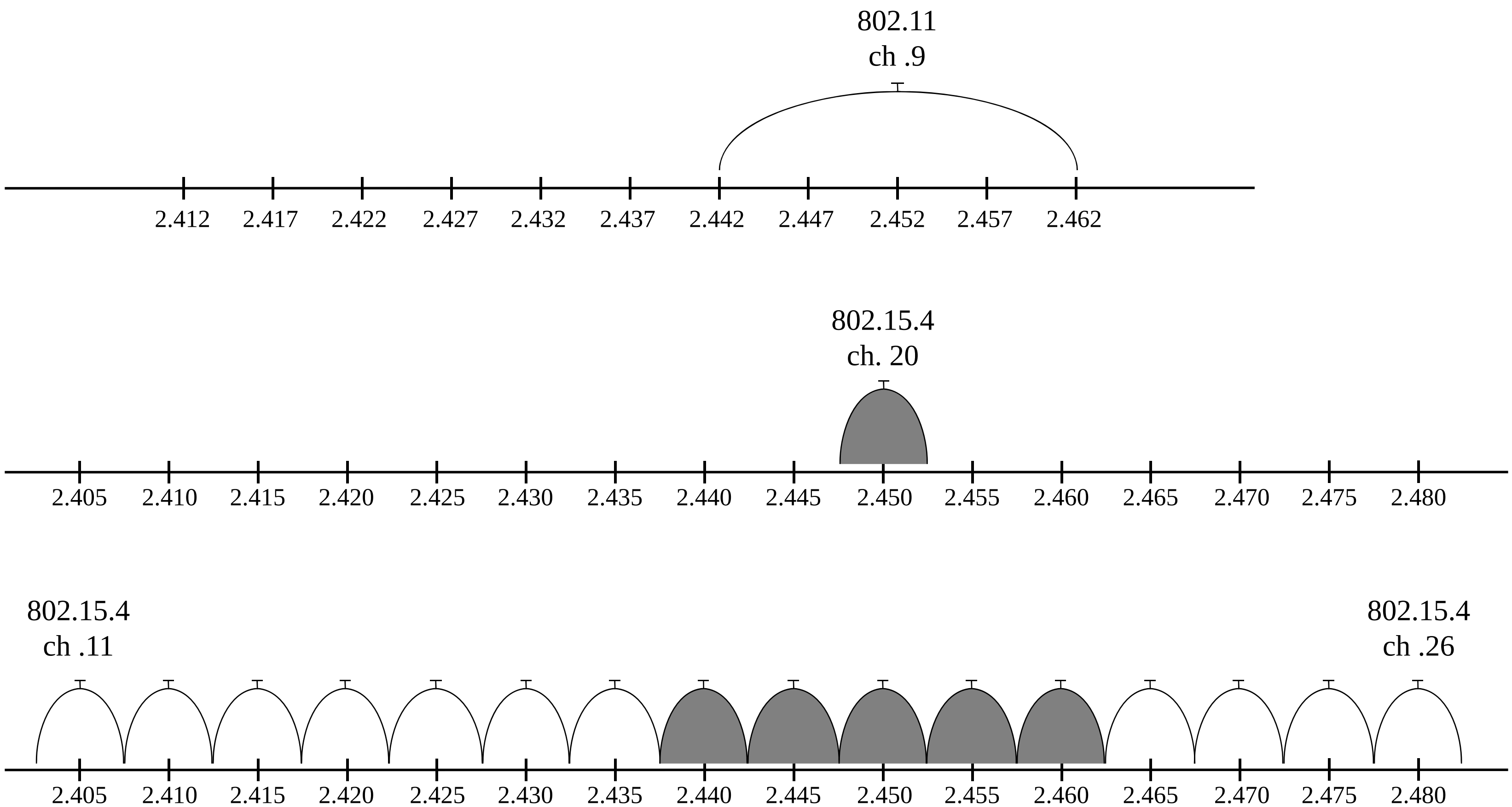
ISA100.11a channels:



ISA100.11a/802.11 Coexistence



ISA100.11a/Zigbee/802.11 Coexistence



WSN Standards Research Topics

JSC wireless habitat test bed provides representative environment for WSN testing. Issues to investigate include:

- RF issues
  - Data delivery reliability – resistance to multi-path, interference, noise
  - Data throughput rate
  - Interoperability – assess impacts on 2.4 GHz 802.11 WLAN
- Power issues
  - Radio/networking component
    - Low power, full mesh networking
  - Sensing/processing component
    - Scheduled sensing
    - Event-driven sensing
- Application issues
  - Feasibility of sensing transient events
  - Usefulness of MAC-derived application time synchronization
- Protocol issues:
  - which protocols best apply when?
  - modifying existing commercial protocols or using as-is
  - investigating future standards-based protocols