IPv6 Embedded Systems and 6LoWPAN Sensor Networks

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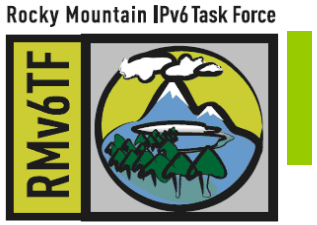
Co-founder, Rocky Mountain IPv6 Task Force
May 26, 2010

Something To Measure



Environmental

- Temperature (°F/°C)
- Humidity (%)
- Pressure (psi/kp)
- Wind speed / direction (mph / m/s)
- Luminosity (Visible, UV)
- Radioactivity (Rad, rem/Sv)
- Chemical detection
- Other

Movement (acceleration, etc.)

- Stress / Strain
- Counting
- Flow (liquid, gas)
- Other

Energy

- Solar (W/m^2 /$erg/cm^2 \cdot s$)
- Geothermal (BTU / kWh)
- Magnetic (G / T)
- Other

Something To Measure

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Multimedia

- Audio / Sound
- Image (Visible, IR, UV)
- Video (Visible, IR, UV)

Geo-Position/Location/Identification

- GPS (geo-location data) [Lat, Long, Alt]
- RF ID (Gen 2-3)

Industry Interest

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- First Responders
  - Police
  - Fire
  - Ambulance
  - FEMA
- SCADIA Networks
- Department of Defense
  - UAV
  - Seismic monitoring
  - Movement
  - Weather
- Building Automation Systems
  - -Utility Companies
  - -Water
  - -Power
  - -Natural Gas
  - -Telco / Cable
- Health Care
  - -Patient Monitoring
  - -Patient location

Why IPv6?

- Each embedded node can be individually addressed/accessed by multiple v6 addresses
  - Security policy attached to each address
- End-to-end security
  - Aux. AES Crypto chip
- Can be built to be low-cost
  - Disposable in the military
  - Address space reuse
- Auto-configuration of network
- Mobility
- IPv4 address exhaustion

IANA/RIR Exhaustion

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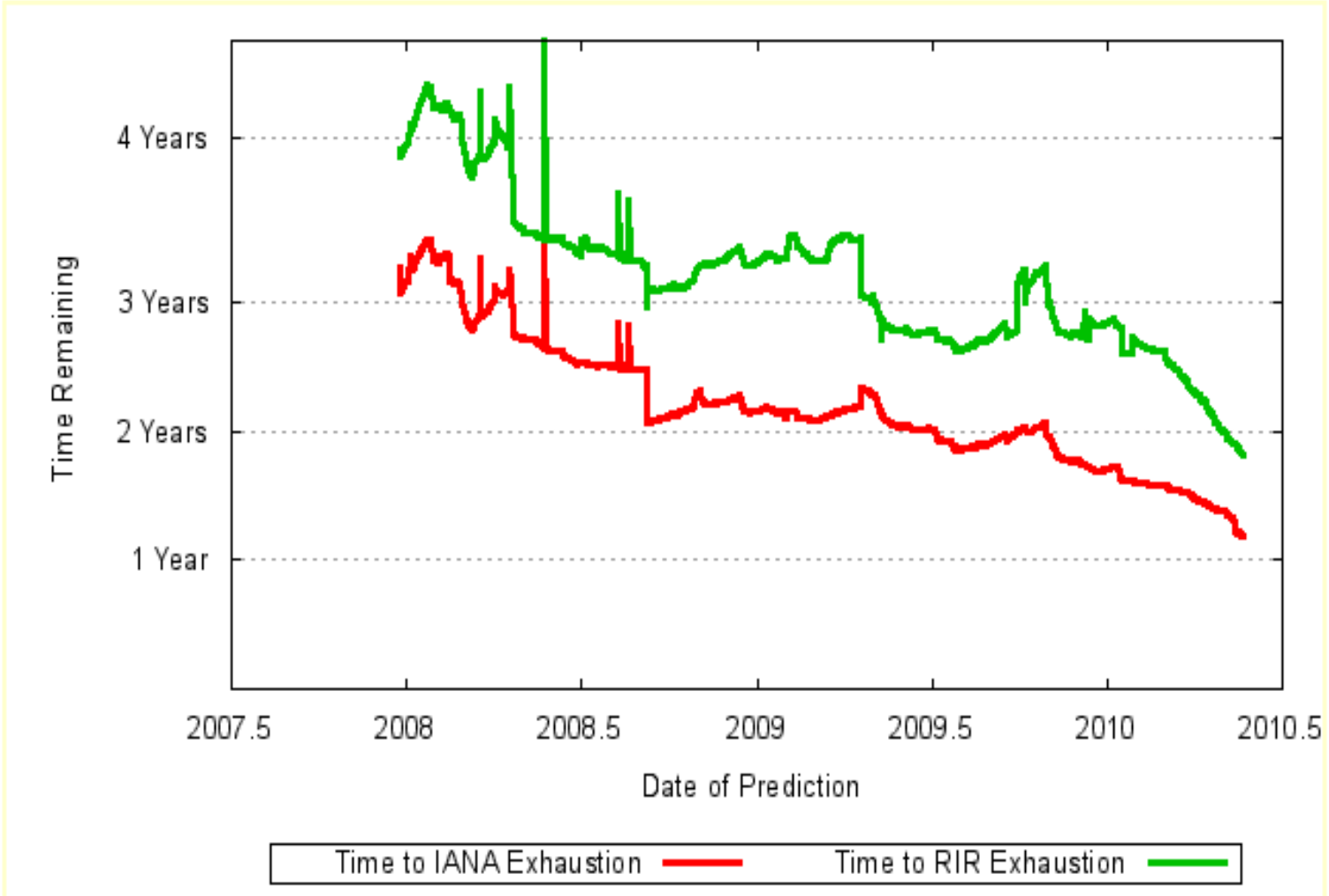
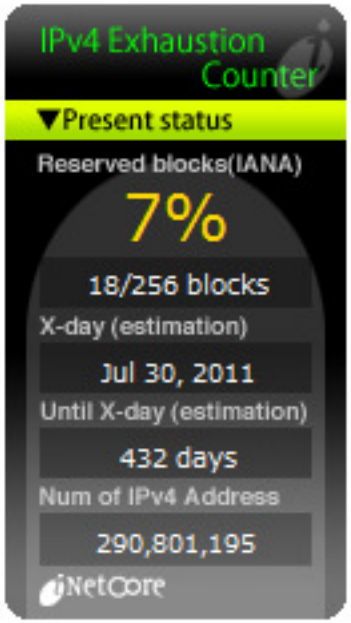


Remaining Pool



Cool Counters at HE website: http://ipv6.he.net/statistics/

http://www.potaroo.net/tools/ipv4/index.html

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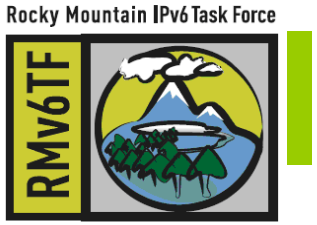
May 2010 IPv4 Exhaustion Status

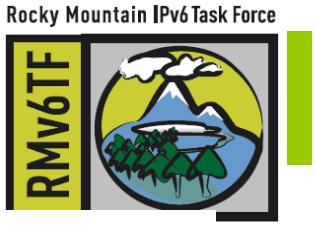
- **Only 18 blocks remain out of the original 256**
- Five are earmarked, one for each RIR when all the other blocks have run out in 2011.
- When the five RIRs have burned through all their remaining holdings, that's it for new IPv4 allocations.
- **Projected IANA Unallocated Address Pool Exhaustion: 30-Jul-2011**
- **Projected RIR Unallocated Address Pool Exhaustion: 16-Mar-2012**
- Internet keeps working – no new v4 addresses

Today's Mobile Platforms



- Laptops, Netbooks
- Mobile Phones (CDMA, GSM, GPRS, UMTS) 3G/4G
- PDAs (Blackberry, iPad, iTouch, etc.)
  - Wi-Fi or cell connectivity
- Embedded Systems (M2M)
  - PC-104 platforms
  - Specialized devices (e.g. embedded microcontrollers)

Remote Platforms

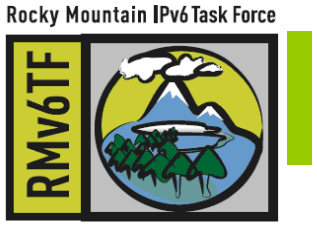


- Future Platforms
  - Trains, Planes, Automobiles, Trucks, Subways, Bikes, Buses, etc.
  - RF ID tags
  - IC Cards
  - Specialty sensors (e.g. Stardust)
  - Boxes, cases, crates, pallets, etc.
  - Power, water, gas meters (some currently now RF capable)

Network Comparison

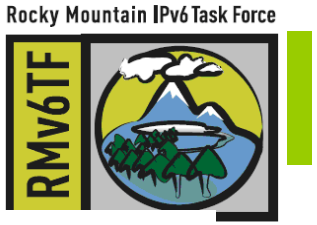
	Traditional Networks	Wireless Sensor Networks
Network Lifetime	Long (years)	Short (days-months)
Network Configuration	Fixed, Static	Dynamic, auto-configuration
Routing Paradigm	Address-centric	Location-centric
Bandwidth	High (Mbps-Gbps)	Low (Kbps)
Routing protocols	BGP, ISIS	MIPv6, OLSR, other
Resource Constraints	Bandwidth, IPv4 address space	Energy, CPU, memory
Applications	Application independent	Application specific (sensor dependent)
Audience	People to people	Machine-to-machine (M2M)
Security	Rich resources to implement	Constrained by available device resources

Wireless Connectivity



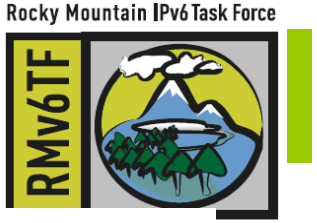
- Wi-Fi (802.11.a/b/g/n)
- WiMax (802.15.4)
- Public Service Radio Frequencies
- 3G/4G (CDMA, UMTS, GPRS, EVDO, etc.)
- Satellite (e.g. Wild Blue), SatPhone

Remote Sensing & Control



- Typically low volume traffic
- Remote areas
  - oil well heads (TX, Middle East)
  - Natural gas pipelines, electric power grid (SCADA)
- Not easily assessable
  - Bridge spans
  - behind enemy lines
  - High rise building core

Limitations on Small Devices



- Battery
  - Long life requires node to “sleep”
- Transmitter power
  - Tx EIRP + environment dictates range
- Security
  - Crypto on separate chip
  - Minimal memory available in small devices
- Bandwidth
  - Low bandwidth devices
- Memory
  - RAM, ROM, Flash

Sensor Mobility

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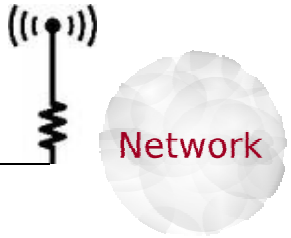
Control/Monitor

Internet

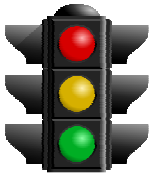
6LoWPAN

UMTS



WLAN

GPRS



Intelligent Transportation System

Biometrics

Telematics

CDMA/EDVO

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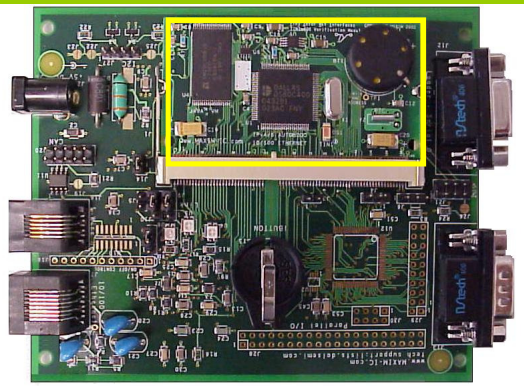
Example Applications

- Localized weather monitoring
- Structural Health monitoring (Earthquake prone areas)
- Battlefield troop detection, movement
- Intelligent Transportation Systems (ITS)
- Green app: Building environment management
  - Lights, HVAC, Security Access, smart power outlets, etc.
  - Building demo - ~20% MRC cost savings

Today's Two Demonstrations:

- Tini Wx Station
- 6LoWPAN demo (802.15.4)

Embedded Systems - TINI



Device: DS80s400 (DSTINIm400): Networked Microcontroller
Performance: 75 MHz, 1 MB Flash, 1 MB RAM
OS: 8051 based java + slush shell (for application development)

- **Commercial off the shelf components**
- **Low cost**
- **IPv6 capable as of Feb 2005**

Sensor selected for demonstration:

- TAI8515 1-Wire Weather Instrument Kit V3.0

Two sensors:

- **anemometer**
- **thermometer**

Three metrics:

- **wind speed**
- **wind direction**
- **temperature**

Item	Qty	Cost
DSTINIs400 micro controller	1	$35.00
DSTINIm400 eval kit/board	1	$67.00
TAI8515 1-Wire Weather Instrument Kit V3.0	1	$75.00
SDK, Application Software		Free
Total Cost		**$177.00**

MSRP List Prices

System Demonstration Diagram

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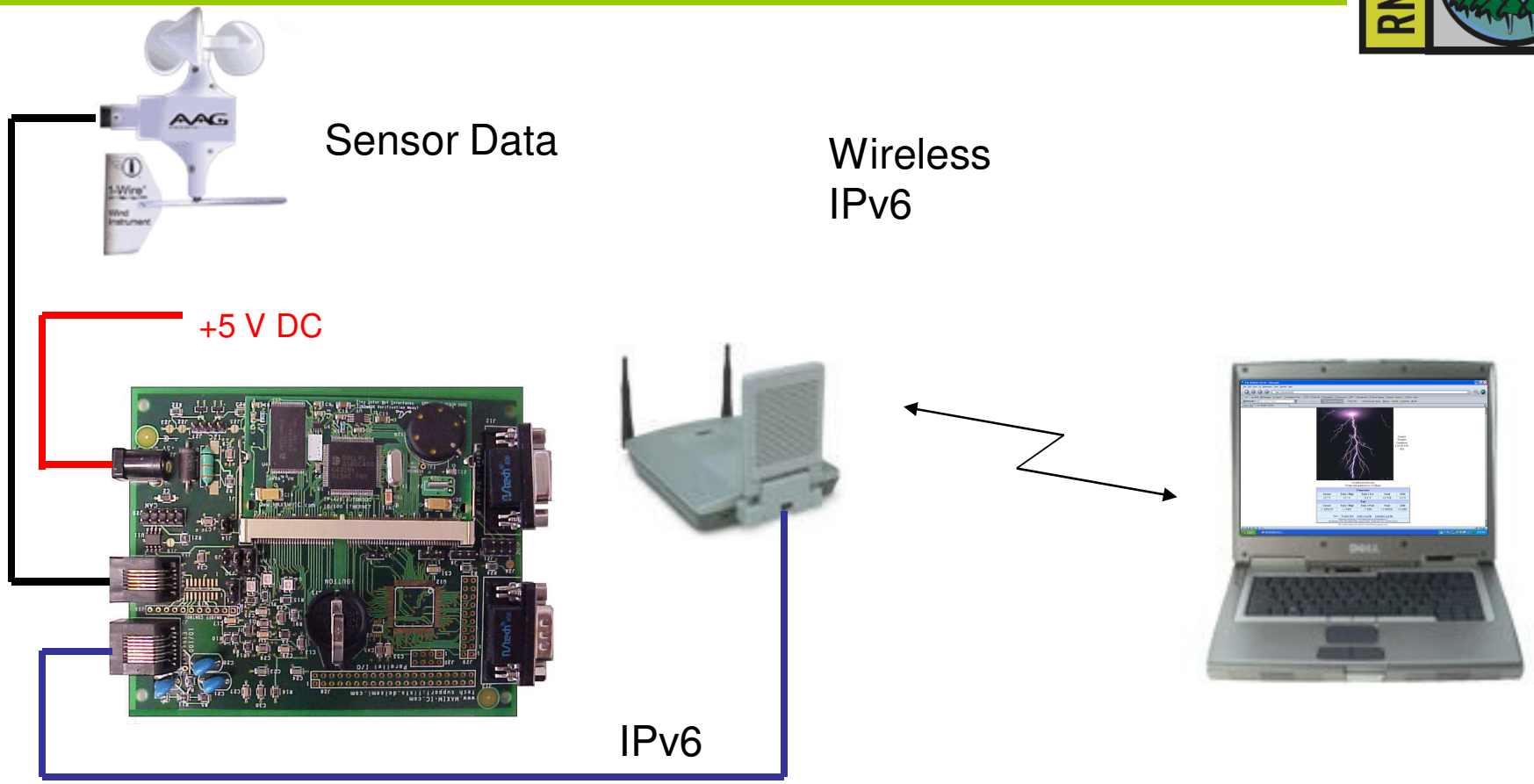

Tiny Internet Network Interface (TINI) microcontroller with web server and java-based web application

Embedded Systems Applications

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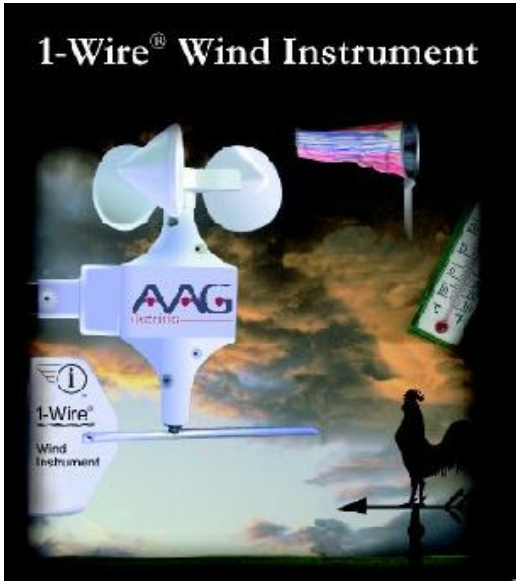
Typical Measurements with Commercial Off The Shelf (COTS) sensor:

- Wind Speed
- Wind direction
- Humidity
- Pressure
- Rain
- Lightning



Add custom configuration with embedded system via:

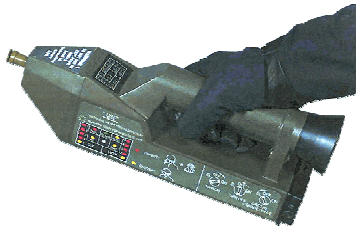
- IPv6
- RS-232 serial port
- 1-Wire® port

Into monitoring/controlling devices:

- Environmental
- WMD
- Automotive
- Point of Sale (PoS)

Custom sensors such as:

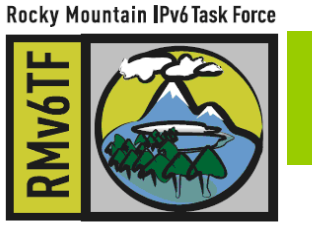
Biological



Chemical

Radiation

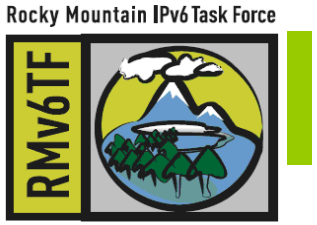
Highlights of IPv6 over 802.15.4



- **Header**
- Standard IPv6 header: 40-bytes [RFC 2460]
  - 802.15.4 MTU is 127-bytes [IEEE standard]
- Fragmentation
  - IPv6 requires all links to support 1280-byte packets [RFC 2460]
  - Interoperability: Applications don't need to know the constraints of physical links which carry the packets
- **Allows link-layer mesh routing under IP topology**
  - 802.15.4 subnets may utilize multiple radio hops per IP hop
  - Similar to Ethernet's LAN switching in IP routing domain
- **IP-based Multi-Hop Routing**
  - RIP, OSPF, IGP,. BGP, AODV, OLSR, others
  - Small routing tables due to microcontroller constraints

RFC 4944 - Transmission of IPv6 Packets over IEEE 802.15.4 Networks

Benefits of 6LoWPAN over 802.15.4



- Excellent capability to work within resource constraints of: low-power, small-memory, lower speed CPU, low-bandwidth
- Leverages IP operational experience in organizations
- Provides interoperability between low-power devices utilizing IP and existing IP infrastructure, using standard routing protocols and techniques

6LoWPAN Network Topologies

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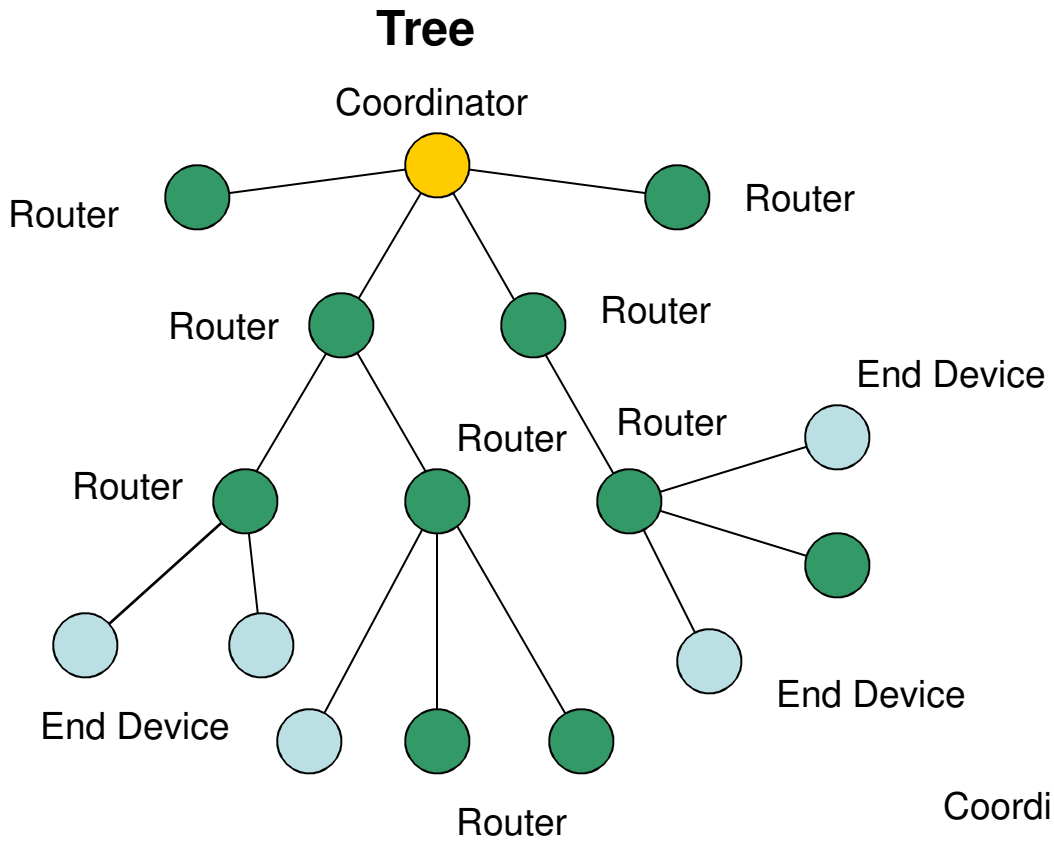

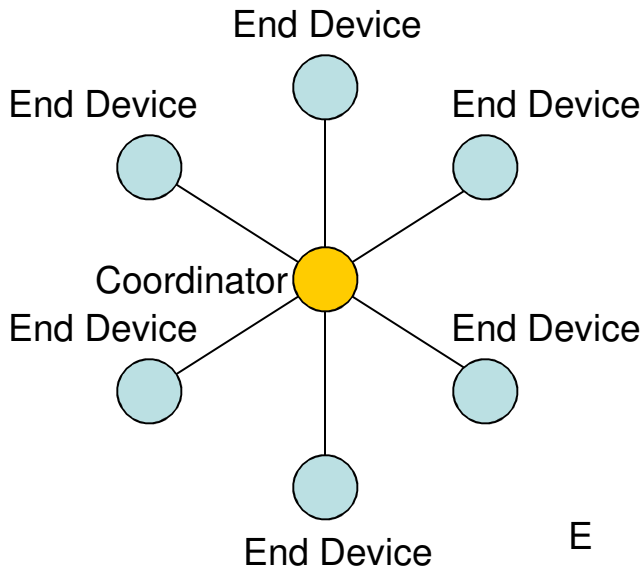

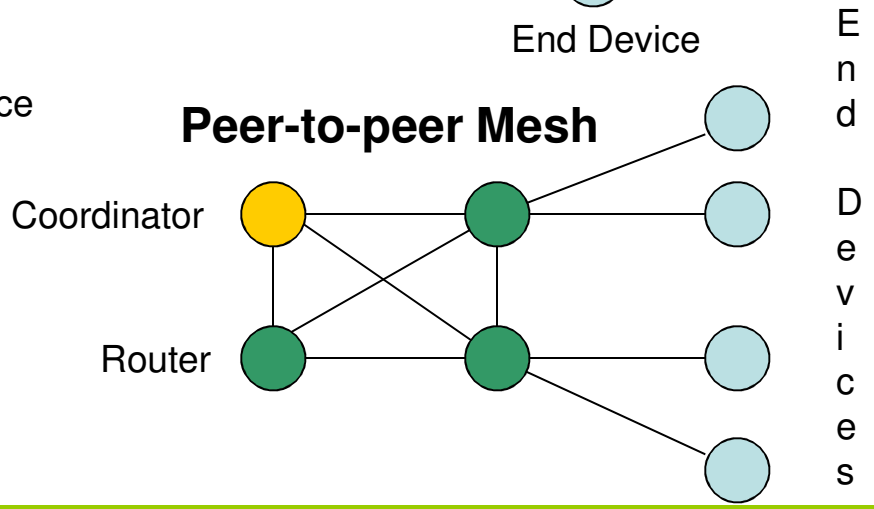

MIPv6 with IPv6 Sensors

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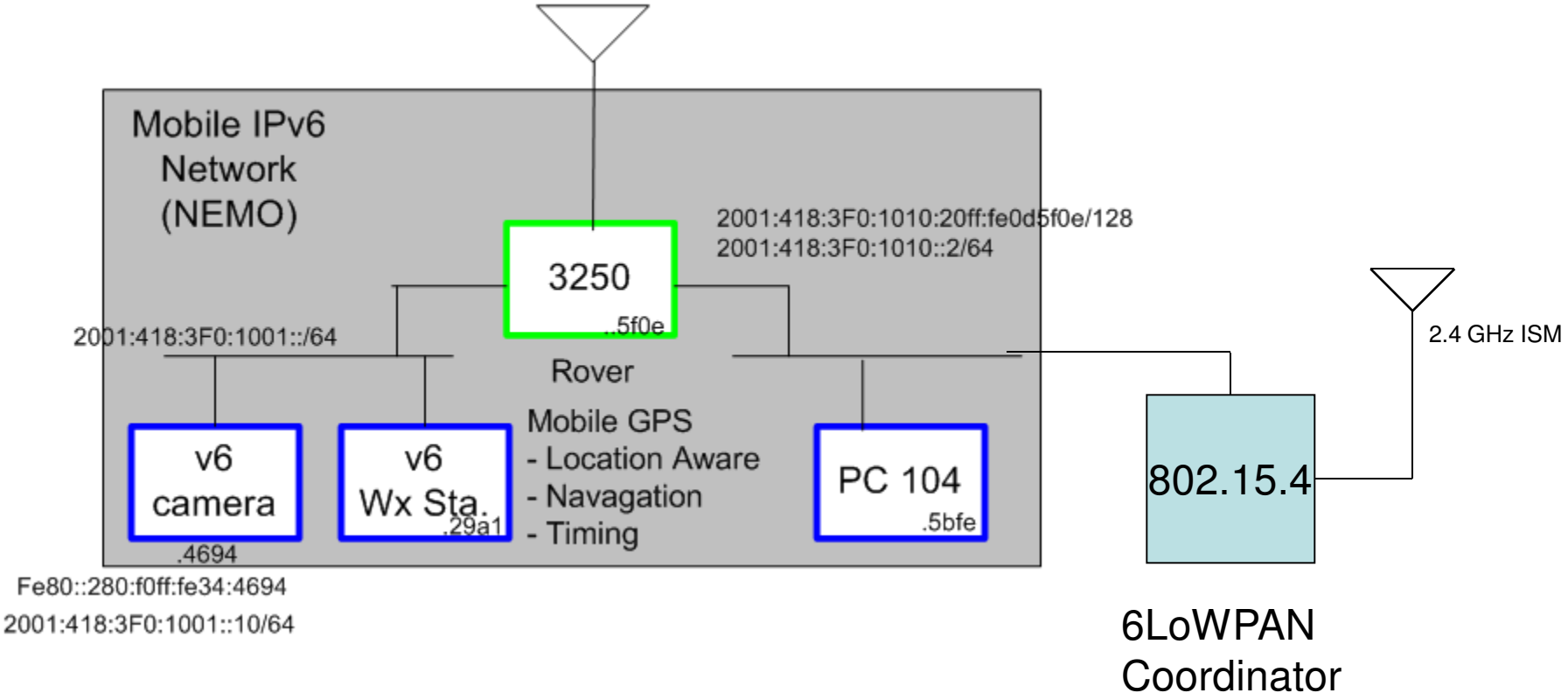
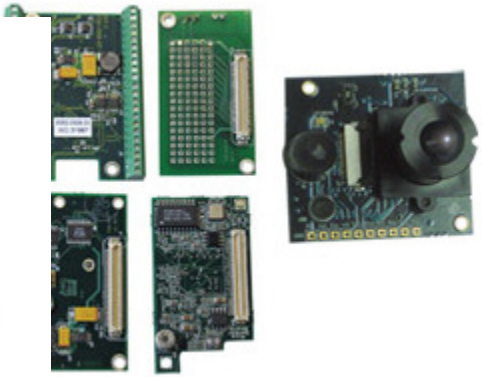
- Rover Demo
  - Cisco 3250 MAR
  - Panasonic Camera
  - PC-104
  - Tini Weather Station

Rover MIPv6 Network

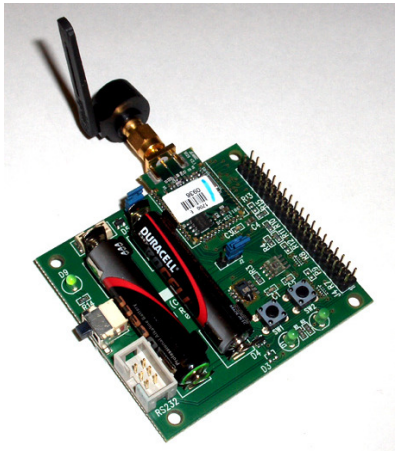


802.15.4 with 6LoWPAN

Atmel Raven



Crossbow

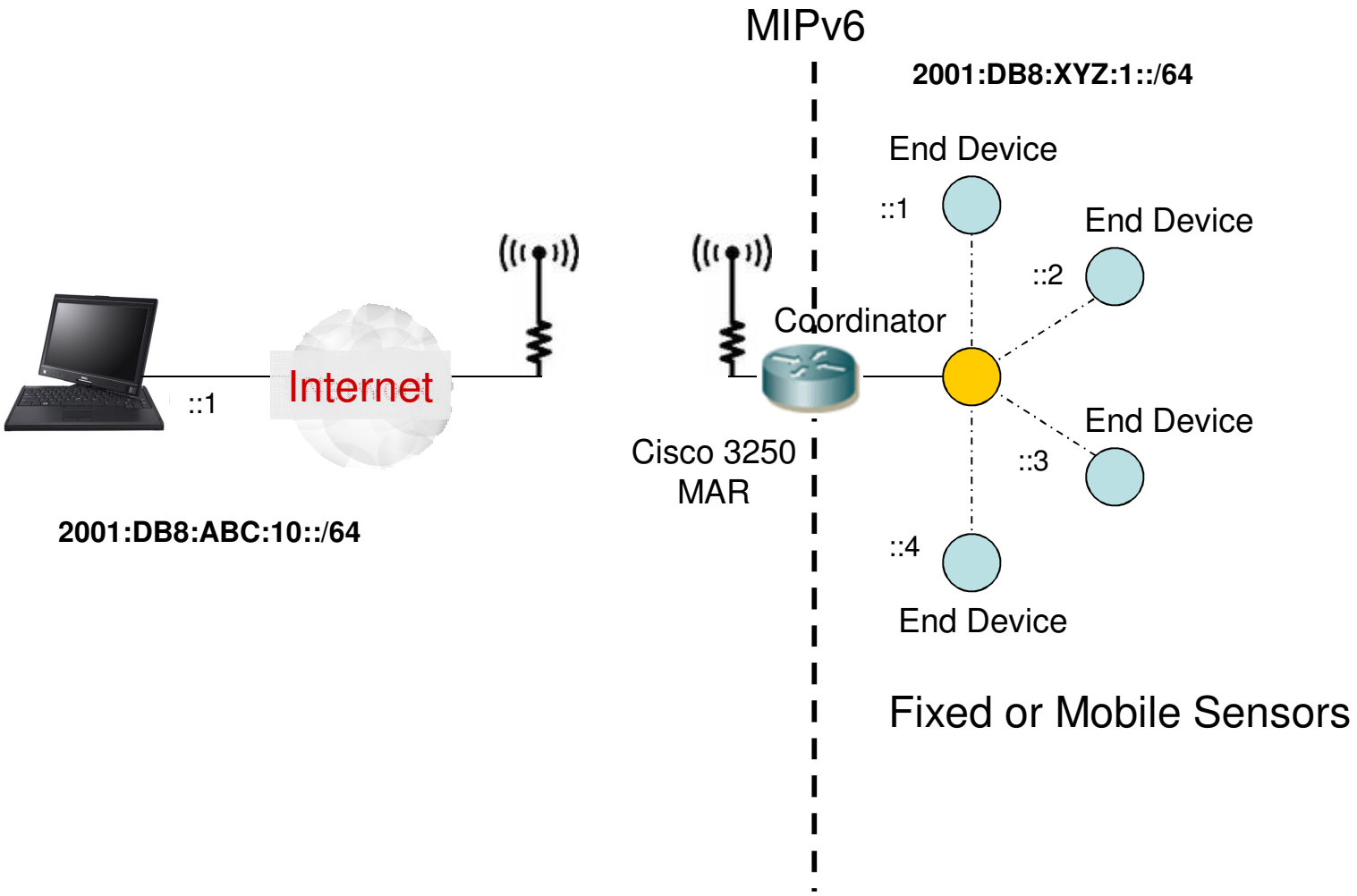


Jennic

Vendors

- Atmel (Raven)
- Crossbow
- Ember
- Epic
- Freescale
- Jennic
- Microchip
- NEC
- Oki
- Radio pulse
- Renesas
- ST
- TI

6LoWPAN


MIPv6
2001:DB8:XYZ:1::/64
End Device
::1
End Device
::2
Coordinator
End Device
::3
Cisco 3250
MAR
::4
End Device
Fixed or Mobile Sensors
Internet
::1
2001:DB8:ABC:10::/64

Q & A

Thank You

Chuck@rmv6tf.org

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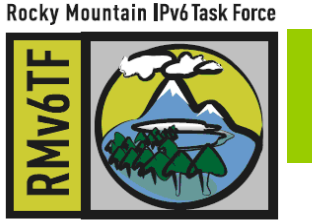
(Selected references follows)

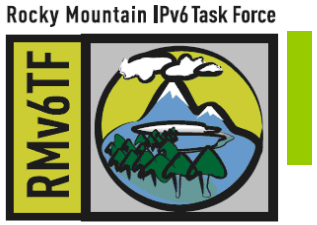
References

URLs



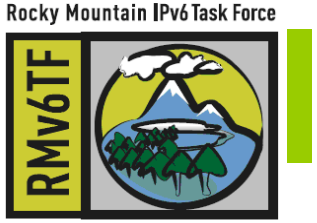
http://nrlsensorsim.pf.itd.nrl.navy.mil/
http://www.scatterweb.com/
http://www.sics.se/

RFCs



- RFC 5340 - **OSPF for IPv6**
- RFC 5308 - **Routing IPv6 with IS-IS**
- RFC 5271 - **Mobile IPv6 Fast Handovers for 3G CDMA Networks**
- RFC 5095 - **Deprecation of Type 0 Routing Headers in IPv6**
- RFC 5094 - **Mobile IPv6 Vendor Specific Option**
- RFC 4944 - **Transmission of IPv6 Packets over IEEE 802.15.4 Networks**
- RFC 4919 - **IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs): Overview, Assumptions, Problem Statement, and Goals**
- RFC 2460 - **Internet Protocol, Version 6 (IPv6) Specification**

Vendors



Archrock – www.archrock.com

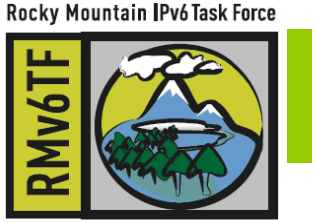
Atmel – www.atmel.com

Crossbow – www.crossbow.com

Dallas Semi/Maxim – www.maxim-ic.com

Jennic – www.jennic.com

Software



- uIP - Open source TCP/IP stack
  - http://www.sics.se/~adam/uip/index.php/Main_Page
  - ARP, SLIP, IP, UDP, ICMP (ping) and TCP protocols.
- TiniOS - *open-source operating system* designed for *wireless embedded sensor networks*
  - http://www.tinyos.net/special/mission
- Free RTOS
  - http://www.freertos.org/