Overview and Experience for External 802.11n on International Space Station (ISS)

Sponsoring Org/Office Code: EV
Name of Forum: CCSDS Spring Meetings
Presenters: Chatwin Lansdowne
Date: April 2018
Topics

Status update since May 2017

• ISS External Wireless Communication subsystem overview
  • Evolution
  • Existing
  • Future

• Experience: what was easy, and challenges
Evolution of EWC

Single-user
Fixed
Point-to-Point

Multiple User
Fixed
Star Network

Multiple User
Fixed/Movable and Mobile
Wireless Network

2016: One WAP, three fixed Clients
2017: Two WAPs, five fixed Clients
2018: Five WAPs, six fixed clients, two transient mobile low-rate clients
2019: More WAPs, fixed clients, three transient mobile high-rate clients
2020: More WAPs, fixed clients, transient mobile high-rate clients
## EWC Committed Users

<table>
<thead>
<tr>
<th>EWC Client</th>
<th>On-orbit Date</th>
<th>Operating Location(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NREP</td>
<td>Operational</td>
<td>JEM-EF; utilization will ramp up</td>
</tr>
<tr>
<td>EHDC</td>
<td>Operational</td>
<td>Truss CP8, CP9, CP13, CP3 planned; coverage coupled to pan-tilt</td>
</tr>
<tr>
<td>MUSES</td>
<td>Operational</td>
<td>ELC-4; utilization will ramp up</td>
</tr>
<tr>
<td>EcoSTRESS</td>
<td>6/2018 SpX-15</td>
<td>JEM-EF site 10; HISUI and NRAL disrupt coverage</td>
</tr>
<tr>
<td>CR15502 EMU Data Recorder</td>
<td>~6/2018</td>
<td>Suited EVA ops</td>
</tr>
<tr>
<td>CR15697 HD EVA Camera Assy</td>
<td>~1/2019</td>
<td>Suited EVA ops</td>
</tr>
<tr>
<td>CR15277 NanoRacks AirLock</td>
<td>10/2019 SpX-18</td>
<td>SSRMS port nadir, POA temp stow truss port nadir</td>
</tr>
<tr>
<td>DDVS</td>
<td>6/2020</td>
<td>SSRMS nadir inspections</td>
</tr>
</tbody>
</table>

- Other 802.11n, coexisting with EWC:
  - JAXA iSEEP payload
  - RRM-3 payload
  - Boeing CST-100
Coverage Expansion Projects

• Approved
  – Node 2 Forward
    • Two WAPs; 4 months from ATP to Launch!
  – Truss
    • Cable runs supporting up to 10 connections for GbE
    • Up to 6 EHDC camera clients dual-purposed or re-purposed as externally mounted WAPs
  – NanoRacks AirLock at Node 3

• Concept
  – Ram shadow
Achievements

• Although not advertised as reliable, EWC has been providing wireless connectivity for multiple high-rate “uplink” users, with very high availability and no complaints
• EWC provides an inexpensive and popular first-choice option to payloads
• EWC leverages
  – worldwide investment in miniaturized COTS, standards, and open-source
  – block-buy investments and accumulation of knowledge about components
  – industry consortium interoperability testing
Tweaks and Challenges

• Wired/wireless cameras and WAP/client-bridge continue symbiosis. However camera viewing angle coupled to antenna pointing angle is not being optimal

• With spacesuits needing to move between IVA and EVA, distinctions between EWC and internal wireless are being erased

• Interoperability: the last 20dB. Behavior depends on specific model of client and specific model of WAP.

• Mobility. Unless clients are aggressive or WAPs are managed, mobile clients do not handoff for best connection
The Current External Wireless System

- The Express Logistic Carrier (ELC) Wireless system provides a COTS solution for external high data rate 802.11n wireless capability to payloads on the ELC

- The system consists of two separate segments
  - US Lab
    - COTS Wireless Access Points (WAP) placed inside the lab with external antennas to provide the core wireless capability
  - Payloads/Users
    - Characterization of a wireless solution for the payloads/users to integrate and provide piece parts to the developers
JSL Architecture – Payload Segment
JSL Logical LAN Overview
Ref: SSP 50892 – Ethernet Requirements for Interoperability with the Joint Station LAN (JSL)

LEGEND:
- Ethernet
- Wireless
Current External Wireless Communications (EWC) Architecture

All Links
Wireless 802.11n
5GHz Band
"US" Regulatory Domain

Initial Config
WAP 1 Connected to both antennas (2x2 MIMO)
WAP 2 Cold Backup (original config)
Pending installation of second WAP connected to the other antenna, so both will be operational
EWC Antenna Coverage Zones

Zenith view

Nadir view

Some Assumptions and Caveats apply.
Achievements

• Communication can inexpensively be provided to payloads and infrastructure by leveraging
  • worldwide investment in miniaturized COTS, standards, and open-source
  • block-buy investments and accumulation of knowledge about components
  • consortium interoperability testing
Challenges: Network and Protocol

• User Interaction
  • A high-rate UDP streamer (e.g. video) can deny service to all users of an access point (inclusive of self), when channel is weak and connection speed drops below stream rate. This is a challenge for moveable or mobile video applications.

• Hidden Node– will happen between port and starboard payloads

• Exposed Node– could happen due to channel reuse
Chronology of 802.11n/ac 5GHz MAC and PHY

USB NIC

- Chipset Release
- Product Release
- Linux driver Release
- Characterization Test
- Radiation Test
- Payload Operations

WAP

- Chipset Release
- Product Release
- Characterization Test
- Flight Operations
- Radiation Test

WAP

- Chipset Release
- Product Release
- Characterization Test
- Flight Operations
- Radiation Test

USB NIC

- Chipset Release
- Product Release
- Radiation Test
- Characterization Test

Module

- 2007
- n Draft 1
- n Draft 2
- WiFi Draft 2.0 “n” testing begins
- 802.11r-2008
- Fast Roaming
- 802.11k-2008
- Radio Resource Measurement
- n Draft 3
- n Draft 4
- n Draft 5
- n Draft 6

- 2008
- n Draft 7
- 802.11n-2009
- Protected Management Frames

- 2009
- 802.11w-2009
- Wireless Network Management

- 2010
- 802.11v-2011

- 2011
- 802.11-2012

- 2012
- 802.11ae-2012
- Prioritization of Management Frames

- 2013
- 802.11aa-2012
- Video Transport Streams

- 2014
- 802.11ac-2013

- 2015
- 802.11ac Wave 2

- 2016
- 802.11ax-2019

- 2017

9 drafts and 3 incorporated standards were released between the time the EWC chipsets were designed, and the release of 802.11-2009. The standard has continued to evolve.

EWC radios are not “WiFi Certified” interoperable.
Penetrations

- Performance of ISS certified NATC / NZGL coaxial bulkheads and connectors is unspecified above 2.5GHz
- Mating performance suffers, as well as crimp performance
- A suitable replacement would enable internal radios with external antennas using carrier frequencies above 2.5GHz

Available and Future technologies?

EXAMPLE 802.11n 40MHz signal, distorted by multipath
Challenges: COTS

• Life of components is generally not specifiable or well-characterized
• NIC and WAP vendors go out of business
• Payloads prefer ISS program provides antennas and NIC

Challenges: Network

• Tendency of payloads to view connection speed not as shared
• Some clients do not support all channels in the country of sale. Clients must support a common channel set for manageability.
Challenges: Radiation

• Roughly 75% of products radiation tested were unsuitable
• 802.11ac adapters are significantly harder than processors. 802.11ac WAPs have had especially soft processors
• Self-corrected failures observed
• Manually recoverable failures observed (soft restart, or hard restart)
• Unrecoverable: a WAP reset configuration to factory default—including the default IP address
• Other failures damaged hardware, even started a fire
Challenges: WAPs and NICs

• Most “802.11n” devices are not “WiFi Certified”
• Some “802.11n” devices on the market today are really “Draft-n”
• Not uncommon for output power or receiver sensitivity of an antenna connection to be 10dB to 30dB degraded after storage on ground
• 802.11ac WAPS generally cannot be configured as clients
Challenges: Antennas

• Rigid antenna mounts: difficult to meet “kick loads” requirements; flexible antenna mounts can be a safety hazard
• Temptation to use dual antennas to increase spherical coverage at expense of network shared capacity and reliability of connection
• Polarization diversity: infrastructure began as vertical and clients had to match. Will become mixed: diverse linear, RHCP
• Temptation to use high-gain antennas and less infrastructure. High-gain antennas become a constraint on infrastructure, and are defeated by maximum EIRP requirement
• Temptation to build antennas in, but then coverage drives box design
COTS, Standards, Open Architecture

- Different standards solve different problems
- Each standard in the infrastructure represents a pool of COTS, tools, software opened to developers

<table>
<thead>
<tr>
<th>Standard</th>
<th>Power</th>
<th>Distance</th>
<th>Data Rate</th>
<th>Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFID</td>
<td>passive</td>
<td>3m</td>
<td>up to ~3kbps</td>
<td>unlicensed</td>
</tr>
<tr>
<td>BLE</td>
<td>harvester, battery</td>
<td>20m</td>
<td>up to ~3kbps</td>
<td>unlicensed</td>
</tr>
<tr>
<td>LoRaWAN</td>
<td>harvester, battery</td>
<td>1km</td>
<td>up to ~3kbps</td>
<td>unlicensed</td>
</tr>
<tr>
<td>ISA-100a</td>
<td>battery</td>
<td>30m</td>
<td>up to ~200kbps</td>
<td>unlicensed</td>
</tr>
<tr>
<td>WiFi</td>
<td>battery, wired</td>
<td>100m</td>
<td>up to ~1Gbps</td>
<td>unlicensed</td>
</tr>
<tr>
<td>LTE</td>
<td>battery, wired</td>
<td>100km</td>
<td>up to ~100Mbps</td>
<td>licensed</td>
</tr>
<tr>
<td>WiGig</td>
<td>wired</td>
<td>50m</td>
<td>up to ~7Gbps</td>
<td>unlicensed</td>
</tr>
</tbody>
</table>

EWC is a best-effort interface. Any interface based on a standard using unlicensed frequencies, is not usable for critical applications.