UNLEASH THE POWER OF LIMITLESS CONNECTIVITY
Wireless Access Network

Why 6 GHz Standard Power Wi-Fi Is The Game Changer For Residential Use In The US

J.R. Flesch
Director, Advanced Technology, Home Networks
Commscope
Asymptotic Achievable Bitrate for 2x2 6E clients

6E delivered TCP bitrate @ 12' range

Goodput @ this range is 2050 Mbps UDP. The implementation scaling factor is 0.868, which includes accounting for TCP overhead.
6E LPI Link Budget Differentials, AP to Client

Tx Throughput vs Attenuation

Client operating point, 12' radius, -6 dB EIRP (per LPI standard)
True operating point, bound by FEMs to +20 dBm

AP operating point, 12' radius to client
Lower Level Wi-Fi House LPI Client Operational Bitrates

<table>
<thead>
<tr>
<th>Lower Level</th>
<th>TCP Mbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>480</td>
</tr>
<tr>
<td>2</td>
<td>650</td>
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<tr>
<td>3</td>
<td>1110</td>
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<tr>
<td>4</td>
<td>880</td>
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<tr>
<td>5</td>
<td>1280</td>
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<td>6</td>
<td>540</td>
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<td>7</td>
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<td>8</td>
<td>540</td>
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<tr>
<td>9</td>
<td>830</td>
</tr>
<tr>
<td>10</td>
<td>970</td>
</tr>
</tbody>
</table>
Lower Level TCP Bitrate Heat Map
Main Level Wi-Fi House LPI Client Operational Bitrates
Main Level TCP Bitrate Heat Map
Top Level Wi-Fi House LPI Client Operational Bitrates

<table>
<thead>
<tr>
<th>TCP</th>
<th>Mbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>200</td>
</tr>
<tr>
<td>2</td>
<td>540</td>
</tr>
<tr>
<td>3</td>
<td>690</td>
</tr>
<tr>
<td>4</td>
<td>960</td>
</tr>
<tr>
<td>5</td>
<td>670</td>
</tr>
<tr>
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<tr>
<td>14</td>
<td>530</td>
</tr>
<tr>
<td>15</td>
<td>300</td>
</tr>
</tbody>
</table>
Top Level TCP Bitrate Heat Map
4W Trunk Performance; 2x2 Client Link Budget

Tx Throughput vs Attenuation

- Pool Room to Living Room Trunk Link: MCS 9, 4W, 45S \(\sim 3.5\) Gbps
- Sample Downlink Operating point, 4W AP
- Sample Uplink Operating point, 20 dBm client

4G b + pathloss Attenuation (dB)
- 11x16 MHz, 4x4
- 11x16 MHz, 2x2
4W Extender 4x4 Trunk Endpoints
Effect of Increasing EIRP from LPI to 4W (Std Pwr)
Spectrum Contenders for 6 GHz
Rationale for Dismissing FSS Interference

- Worst-case legacy I/N (~-5 dB max)
- Worst-case indoor I/N (~-22 dB max)
Cloud AFC System Componentry

- NRA Incumbent Database
- NRA Equipment Authorization Database
- NRA Database Update Function
- Spectrum Availability Function
- AFC Device Responder Function
- AFC Internal Database Function
- Incumbent Protection Function
- Activity Logging Function
- AFC System Key Functions (Total 6)
- US Topographical Database

AFC System to AFC Device Interface

SUT Test Plan & Test Vectors

AFC Device, Fixed Client Device or Proxy

DUT Test Plan & Test Vectors
Cloud AFC System Componentry (Cont.)

Architecture/Function Parsing

- **NRA (Nat’l Regulatory Authority) Database Update Function**
  - DB of incumbent links w/locations, descriptors and credentials (maintained)

- **AFC Device Responder Function**
  - Duplex cloud link (URL based) which provides HTTPS/JSON portal for AFC device comms

- **Spectrum Availability Function**
  - Generates payload for response messages to devices (incl. error msgs)
  - Invokes Incumbent Protection Function and Logging Function

- **Incumbent Protection Function**
  - Math engine to do interference calculations (both CCI and adjacents) and recommend permissible channels (and operating power levels)

- **Logging Function**
  - Creates/maintains “non-repudiable ledger” of AFC transactions

- **AFC Internal DB Function**
  - Largely parametric details on incumbent installations (as antenna pattern specs and related)
AFC Cloud Portal Messaging

- **Northbound (device to cloud)**
  - Available Spectrum Inquiry Request
    - Unique ID
    - Device Descriptors
    - Location Detail
    - Inquired Freq Range (MHz) and/or
    - Inquired Channel Numbers
    - Minimum Desired Power (dBm or dBm/MHz)
    - Vendor Extensions

- **Southbound (cloud to device)**
  - Available Spectrum Inquiry Response
    - Unique ID (per upstream request)
    - Allowable PSD by Freq Range (dBm/MHz) and/or
    - EIRP by List of Channels
    - Expiration time for provided ops (GMT)
    - Response Codes (P/F and error codes)*
    - Vendor Extensions

*Pass/Fail, with codes 100-199 being reserved for errors related to message formation, authentication, etc and 300-399 for tech editing concerns (like requesting inappropriate/wrong channels)
AFC Messaging Supplemental Detail

- **Device Descriptor** is a 3-tuple: serial #, FCC ID# and (for US) a text string “47_CFR_PART_15_SUBPART_E” (would be different for other countries)

- **Location** is longitude, latitude and height (as degrees relative to the central meridian, degrees relative to the equator and meters above local terrain). The location footprint of the AP(s) in question may be expressed as an ellipse or 1 of 2 versions of a polygon area. Uncertainty self-certified (but reported) and an enumerated field describes whether the unit is indoor or out.

- **Inquired Freq Range** is as “a-b” where a, b are in MHz

- **Inquired Channels** is an explicit list of requested channel numbers
Use of AP Proxy to Facilitate Cloud Communications
Common FS Antenna Apertures (Azimuth)
Zoomed Perspective Showing Look Angle Selectivity
Low Use Incidence “Cheap” FS Antenna Aperture (.9m)
FCC Requirements for Wi-Fi Adjacent Channel Performance

Single-sided OOB energy mask for LPI and standard power Wi-Fi

-20 dB
-28 dB
-40 dB

Band Edge
Band Edge + 1 MHz
Fc + 1 * channel BW
Fc + 1.5 * channel BW
Anticipated Guard Bands for FDM of Wi-Fi and FS

- Nearest lower sideband Wi-Fi 160 MHz channel
- Nearest upper sideband Wi-Fi 160 MHz channel
- FS channel to be protected
- 80 MHz
- 1 MHz
AP WAE Considerations for Client Band Mounts

WAE Block Diagram:

- Rules:
  - Wi-Fi 6 > Wi-Fi 5 > other
  - 6 GHz > 5 GHz > 2.4 GHz
  - Maximize Chan BW
  - Maximize SS
  - Preferred chan order/band

- per-client op profile cache
  - (MCS, data rate, band, channel # and BW, MAC, SS, timestamp)

- logs + queries
- utilization

- AirTime Calculator
  - \[ \sum \text{Rate/Capacity} \text{ all links} \]
  - for each of 2.4, 5 and 6 GHz

- FCC governance
  - 6 GHz channel # & mask

- Wi-Fi Airtime Engine
  - op profile data
  - op profile data
WAE Process for Mounting Clients into Wi-Fi Network

1. New client activity
2. Is historical profile available?
   - Y: Retrieve op profile (MCS, data rate, band, channel#, BW, SS, MAC)
   - N: Establish client op limits: MCS, bands, MAC, BW and SS count
3. AirTime Calculator
4. Rank-order band utilizations against client band subscription
5. Rules/Preferences
6. Apply rules and preferences to client/band assignment
7. Assign client to band and log in active device queue
8. Op Parameter Cache
Some Necessary Coexistence Operational Overhead

Background Channel Scanning

* Particularly important for 6 GHz due to the potential for unlicensed channel competition from NRU elements

* May be optimized for data “freshness” versus overhead burden and historical profiles of competing signals

* Builds a perspective of CCI based upon channel, BW and detected energy level

* Provides for Vendor Differentiation as regards clarity, utility and airtime cost
Lower Level 2x2 Client Coverage w/4W Mid-Home AP
Main Level 2x2 Client Coverage w/4W Mid-Home AP
Top Level 2x2 Client Coverage w/4W Mid-Home AP
Repositioning Extender to Top Floor, Opposite Third
Effect of the Repositioned Extender

* With the exception of the locked storage region in the basement, all areas of the home are blanketed with an average of 1.7 Gbps (so all are orange colored).

* A client device in the locked storage area would still prefer to associate with the top floor extender, but its coverage would drop to ~ 1.25 Gbps TCP.

* The farther trunk throw to the extender (now up on the 3rd floor), reduces its duplex 4x4 bitrate to 2.5 Gbps (versus the 3.5 for a midpoint extender).
Removing the Extender Altogether

Now the entire home is services from the 4W WAN gateway

* Examining the worst-case location, in the far corner of the 2nd bedroom upstairs to establish minimum expected bitrate service:

  * 62’ of 3D service radius + 2 floors + 3 walls worth of path loss

  * Downlink bitrate still > 1 Gbps (1030 Mbps).

  * Uplink bitrate ~ 275 Mbps – so client remains enfranchised in the network
Thank You!

J.R. Flesch
Director, Advanced Development, Home Networks
Commscope
Jr.flesch@commscope.com