6 GHz Low Power Indoor (LPI) Wi-Fi / Fixed Service Coexistence Study
6 GHz Wi-Fi Is Essential to

• The cable industry has nearly saturated its US footprint with gigabit broadband service
• Gigabit broadband is the foundation of 10G, which CableLabs is building along with our members
• Wi-Fi is how consumers access their broadband service, and the Wi-Fi link must perform at the same level
• Wider channels, greater bandwidth, higher efficiency provided by 6 GHz Wi-Fi is essential to the realization of 10G
• Multi-gigabit, low latency, highly reliable broadband is the 10G vision, but additional unlicensed spectrum is required to make this a reality
Executive Summary

• There have been many technical analyses filed in the FCC record in the 6 GHz proceeding

• CableLabs recognizes the importance of suitable incumbent protection in the 6 GHz band

• CableLabs has worked with its members to gather real-world airtime utilization data as a key input to 6 GHz coexistence analysis

• Analysis incorporating operational network data proves that LPI Wi-Fi can coexist with FS without harmful interference
  • Conservative simulation of aggregate noise incorporates this Wi-Fi airtime utilization data and other real-world data such as LIDAR ranging and realistic ranges for relevant parameters, which shows that I/N does not reach even the conservative -6 dB threshold
  • We increase the robustness of our conclusion through a sensitivity analysis that shows that even unrealistically high levels of noise that exceed our simulation-based observations do not impact FS availability
Wi-Fi Airtime Utilization Data

• 500,000 Wi-Fi access points were polled for airtime utilization
• 15-minute measurement intervals, hourly, 24 hours/day over 10 days
  • All Wi-Fi activity, data and management frames
• Wide geographic representation in AP sample
• Yielded 450 million data points, representing the most comprehensive data set available on the record
• This data was recently filed by Broadcom in a Dec. 9th Ex Parte
Wi-Fi Airtime Utilization Data

• 5 GHz Measurement results:
  • 99th percentile peak utilization is 7%
  • 95th percentile peak is 2%
  • 90th percentile peak is 1%

➢ For entire data set, weighted average is 0.4%
Wi-Fi Airtime Utilization Data: Analysis

• We can use the full data set to analyze coexistence between LPI Wi-Fi and FS. We accomplish this through two approaches:

  1) A realistic simulation of aggregate interference to a representative FS link (New York City case study)
  2) A sensitivity analysis of what unrealistically high levels of noise from Wi-Fi mean for FS availability

• We can also use this data to anchor existing technical studies on the record
Interference Simulation

Aggregated RLAN interference to a representative FS link in Manhattan, using real-world Wi-Fi activity data
Method

- Derive aggregate RLAN interference to a representative FS link in NYC, using real-world RLAN airtime utilization data and reasonable ranges of relevant parameters, including:
  - Aggressive 6 GHz RLAN growth (1,000 APs/km² using 6 GHz) and accurate in-market deployment (including height from USGS LIDAR data)
  - Realistic and appropriate distributions of RLAN channel bandwidth, power and antenna pattern, path and building loss
  - Representative FS link in Manhattan using actual antenna pattern and ULS location / height data

- Simulate realistic RF system interactions using bandwidth and geometric overlap
  - Matlab using Monte Carlo approach over 1500 iterations

- Results provide a realistic risk-informed view of interference risk to FS that should be the basis of FCC decision making

- Output is depicted as cumulative distribution of probability of aggregate interference at various intensity levels
Results

- I/N Results with low incumbent height
  - Max: -8.5 dB
  - Median: -21.9 dB
- I/N Results with high incumbent height
  - Max: -29.7 dB
  - Median: -36.7 dB
- Simulation shows that LPI Wi-Fi will not cause harmful interference to FS even at a conservative -6 dB I/N threshold
Noise Rise Sensitivity Analysis
Fading and Noise Rise

• Our simulation showed that even with conservative assumptions and dense deployment, no chance of exceeding I/N of -6 dB

• Some corner cases on record suggest specific theoretical and very unlikely situations in which a 30 dBm EIRP Wi-Fi AP would cause a significant noise rise

• But: When a fixed link is engineered with fade margins to provide five-nines availability (99.999%) or higher, even an unrealistically high 10 or 20 dB noise rises creates no increase in FS outage time
  • Given other mechanisms used by FS – frequency and antenna diversity, for instance – availability of critical FS links is engineered to be much higher than 99.999%
FS links are designed with fade margin so that outages are 5 minutes per year (99.999% avail)

- Even with unrealistically high noise rise, and assuming no other margins, FS links see no reduction in availability
  - Even a reduction in availability would not necessarily lead to an outage because FS utilization will be less than 100%

In a scenario where 30 dBm EIRP Wi-Fi would cause unrealistic 10 dB noise rise, FS availability remains 99.999%

In a scenario where 30 dBm EIRP Wi-Fi would cause unrealistic 20 dB noise rise, FS availability remains at 99.999%
Results Confirm Oct. 2019 Fading Study

• Showed that even when fading is at its worst for a 95th percentile FS link (worst case), five-nines reliability and more can be achieved.

• Wi-Fi network data confirms this.
  • Wi-Fi network operator results show 7% airtime utilization at 99% percentile which would yield availability to greater than 99.9998%
  • Average Wi-Fi airtime utilization of 0.4% yields FS availability of 99.99999%

95th percentile FS Link with Unrealistic Interference (+20dB I/N, Duty Cycles < 100%)
Minimal Degradation with Realistic Duty Cycles

• Taking into account real-world RLAN duty cycles reduces the effect even further.
• Link maintains availability greater than five-9s even with 35% duty cycle (far higher than studies predict for 6 GHz RLAN devices).
• As in the earlier example, this does not take into account that:
  • An RLAN is far less likely to be transmitting in the middle of the night/early morning when deep fades are most likely
  • The FS likely has inter-frame spacing between its data packets and may not be operating at maximum capacity
  • The FS has a spatial diversity antenna that is expected to handle 99% of deep fade events
  • Critical links may also have redundant rings, use frequency diversity, and have fiber as a primary or back-up

<table>
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<tr>
<th>Interference</th>
<th>Throughput Reduction (Worst Month)</th>
<th>Availability (Worst Month)</th>
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<tr>
<td>Continuous</td>
<td>0.1939%</td>
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<tr>
<td>2%</td>
<td>0.0039%</td>
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<tr>
<td>1%</td>
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<td>0.50%</td>
<td>0.0010%</td>
<td>99.999990%</td>
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October 7, 2019 Ex Parte, Paul Margie, Harris Wiltshire Grannis
Conclusion

• Analysis of real-world airtime utilization data shows that FS will not experience harmful interference from LPI Wi-Fi operations.

• This data validates studies on the record supporting RLAN coexistence with FS; our realistic simulation and sensitivity analysis further validate conclusions.

• The FCC should therefore support continued advancement of broadband access technology by making 6 GHz available for LPI unlicensed operations across all 1200 MHz without AFC.
Appendix: Simulation Parameters
Empirical Data on Airtime Utilization

• Airtime utilization contributes to the probability of interference from RLAN to FS

• Collected data from 500k 5 GHz APs across the U.S.
  – Zoomed-in CDF is shown; entire data set integrated into simulation
  – Residential APs were polled; enterprise APs have lighter usage*
  – Airtime utilization includes transmitting and receiving time of an AP

• Weighted average airtime utilization: 0.4%

RLAN Parameters in the NYC Simulation

• Volume:
  • Use 6 GHz sales forecast (ABI Research) extrapolated to 10-year window (~60% market penetration, which is higher than ECC Report 302)
  • NTIA Internet Use survey provides proxy for Wi-Fi density (75% of households)
  • Adopt a bandwidth-proportionate 6 GHz signal proration (63% of total Wi-Fi bandwidth)
  • Yields an effective NYC 6 GHz Wi-Fi active footprint of ~800,000 access points (approx. 1,000 APs/km² using 6 GHz)

• Location: Distributed across the NYC market, and layered vertically based on LIDAR building data from USGS

• Bandwidth & Power:
  • Use distributions aligning with ECC Report 302

• Antenna pattern taken from commercial products

<table>
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<tr>
<th>Indoor Tx EIRP</th>
<th>1000mW</th>
<th>250mW</th>
<th>100mW</th>
<th>50mW</th>
<th>13mW</th>
<th>1mW</th>
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<tr>
<td>RLAN %</td>
<td>1%</td>
<td>12%</td>
<td>6%</td>
<td>19%</td>
<td>54%</td>
<td>8%</td>
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<table>
<thead>
<tr>
<th>Channel Bandwidth Distribution</th>
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</thead>
<tbody>
<tr>
<td>Channel BW</td>
</tr>
<tr>
<td>RLAN %</td>
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</table>

Bandwidth and power values taken from ECC Report 302. Note that power distribution extracts the AP-side information from Table 6 of Report 302, and excludes lower-power client-side information.
FS Parameters in the NYC Simulation

• Representative FS link in Manhattan
  • Two heights modeled – 90th and 10th percentile – based on FCC ULS data for NYC

• 25 MHz bandwidth
• FS antenna
  – Commscope’s HSX6-64B dish antenna
  – Max gain: 40 dBi
  – HPBW: 1.7° in both vertical and horizontal planes
  – Has more gain in both planes than other antenna on the market, therefore is conservative

• Noise figure: 5 dB (noise floor: -95 dBm)
Bandwidth and Geometric Interactions

• Simulation calculates the probability of channel overlap between RLAN and fixed service, based on the realistic parameters we have outlined

• We also integrate information on RLAN and FS physical deployment
  • RLANs uniformly distributed in NYC market, and allocated height based on LIDAR data
  • FS receiver height taken from in-market FCC data
  • Enables integration of FS antenna pattern information for realistic angle of RF incidence
    • Corner-case interactions are therefore represented in the simulation
Other RF Parameters

- WINNERII Urban path loss model used
  - Appropriate for NYC market that is the focus of this simulation
- Building entry loss represented as a distribution between 10 dB and 30 dB
  - Captures a range of building material factors and indoor AP placement possibilities
  - Consistent with ITU-R P.2109 for relevant cases