FORMATO PARA PARTICIPAR EN LA CONSULTA PÚBLICA

Instrucciones para su llenado y participación:

I. Las opiniones, comentarios y propuestas deberán ser remitidas a la siguiente dirección de correo electrónico: planeación.espectro@ift.org.mx, en donde se deberá considerar que la capacidad límite para la recepción de archivos es de 25 MB.
II. Proporcione su nombre completo (nombre y apellidos), razón o denominación social, o bien, el nombre completo (nombre y apellidos) de la persona que funja como representante legal. Para este último caso, deberá elegir entre las opciones el tipo de documento con el que acredita dicha representación, así como adjuntar –a la misma dirección de correo electrónico- copia electrónica legible del mismo.
III. Lea minuciosamente el **AVISO DE PRIVACIDAD** en materia del cuidado y resguardo de sus datos personales, así como sobre la publicidad que se dará a los comentarios, opiniones y aportaciones presentadas por usted en el presente proceso consultivo.
IV. Vierta sus comentarios conforme a la estructura de la Sección II del presente formato.
V. De contar con observaciones generales o alguna aportación adicional proporciónelos en la sección III del presente formato (último recuadro).
VI. En caso de que sea de su interés, podrá adjuntar a su correo electrónico la documentación que estime conveniente.
VII. El período de consulta pública será del 28 de mayo al 24 de junio de 2021(i.e 20 días hábiles). Una vez concluido dicho periodo, se podrán continuar visualizando los comentarios vertidos, así como los documentos adjuntos en la siguiente dirección electrónica: http://www.ift.org.mx/industria/consultas-publicas
VIII. Para cualquier duda, comentario o inquietud sobre el presente proceso consultivo, el Instituto pone a su disposición el siguiente punto de contacto: Xochitl Citlalli Hernández Medina, Subdirectora de Coordinación Técnica en Radiocomunicación, correo electrónico: xochitl.hernandez@ift.org.mx, número telefónico 55 5015 4000, extensión 2317 y; Juan Pablo Rocha López, Director de Atribuciones de Espectro, correo electrónico: juan.rocha@ift.org.mx o bien, a través del número telefónico 55 5015 4000, extensión 2726.

I. Datos de la persona participante	
Nombre, razón o denominación social:	Dynamic Spectrum Alliance, DSA
En su caso, nombre de la persona que funja como representante legal:	Martha Liliana Suárez Peñaloza
Documento para la acreditación de la representación: En caso de contar con una persona que funja como representante legal, adjuntar copia digitalizada del documento que acredite dicha representación, vía correo electrónico.	Carta Poder

AVISO DE PRIVACIDAD INTEGRAL DE DATOS PERSONALES QUE EL INSTITUTO FEDERAL DE TELECOMUNICACIONES RECABA A TRAVÉS DE LA UNIDAD DE ESPECTRO RADIOELÉCTRICO

En cumplimiento a lo dispuesto por los artículos 3, fracción II, 16, 17, 18, 21, 25, 26, 27 y 28 de la Ley General de Protección de Datos Personales en Posesión de Sujetos Obligados (en lo sucesivo, la "LGPDPPSO"); 9, fracción II, 15 y 26 al 45 de los Lineamientos Generales de Protección de Datos Personales para el Sector Público (en lo sucesivo los "Lineamientos Generales"); 11 de los Lineamientos que establecen los parámetros, modalidades y procedimientos para la portabilidad de datos personales (en lo sucesivo los "Lineamientos de Portabilidad"), numeral Segundo, punto 5, y numeral Cuarto de la Política de Protección de Datos Personales del Instituto Federal de Telecomunicaciones, se pone a disposición de los titulares de datos personales, el siguiente Aviso de Privacidad Integral:

I. Denominación del responsable
Instituto Federal de Telecomunicaciones (en lo sucesivo, el "IFT").

II. Domicilio del responsable
Avenida Insurgentes Sur #1143, Colonia Nochebuena, Demarcación Territorial Benito Juárez, Código Postal 03720, Ciudad de México.

III. Datos personales que serán sometidos a tratamiento y su finalidad
Los datos personales que el IFT recaba, a través de la Unidad de Espectro Radioeléctrico, son los siguientes:

- *Datos de identificación: Nombre completo y Correo electrónico.*
- *Datos patrimoniales y de identificación: Documentos que acreditan la personalidad como el nombre del representante de persona física o moral y que por su naturaleza contienen datos personales, de manera enunciativa más no limitativa: Nacionalidad, Estado Civil, Domicilio, Patrimonio, Firmas, Rúbricas.*
- *Datos ideológicos: Comentario, Opinión y/o Aportación.*

Se destaca que en términos del artículo 3, fracción X de la LGPDPPSO, ninguno de los anteriores corresponde a datos personales sensibles.

IV. Fundamento legal que faculta al responsable para llevar a cabo el tratamiento
El IFT, a través de la Unidad de Espectro Radioeléctrico, lleva a cabo el tratamiento de los datos personales mencionados en el apartado anterior, de conformidad con los artículos *15, fracciones XL y XLI, 51 de la Ley Federal de Telecomunicaciones y Radiodifusión , última modificación publicada en el Diario Oficial de la Federación el 31 de octubre de 2017,12, fracción XXII, segundo y tercer párrafos y 138 de la Ley Federal de Competencia Económica, última modificación publicada en el Diario Oficial de la Federación el 27 de enero de 2017, así como el Lineamiento Octavo de los Lineamientos de Consulta Pública y Análisis de Impacto Regulatorio del Instituto Federal de Telecomunicaciones, publicados en el Diario Oficial de la Federación el 8 de noviembre de 2017*, recabados en el ejercicio de sus funciones.

V. Finalidades del tratamiento
Los datos personales recabados por el IFT serán protegidos, incorporados y resguardados específicamente en los archivos de la Unidad de Espectro Radioeléctrico, y serán tratados conforme a las finalidades concretas, lícitas, explícitas y legítimas siguientes:

A. *Divulgar íntegramente la documentación referente a los comentarios, opiniones y/o aportaciones que deriven de la participación de las personas físicas en los procesos de consulta pública a cargo del IFT.*
B. *Hacer llegar al IFT, mediante la dirección electrónica habilitada para ello, su participación en los procesos de consulta pública.*
C. *Acreditar la personalidad en caso de que los comentarios, opiniones y/o aportaciones, u otros elementos de los procesos consultivos sean presentados por los interesados a través de representante legal.*

VI. Información relativa a las transferencias de datos personales que requieran consentimiento
La Unidad de Espectro Radioeléctrico no llevará a cabo tratamiento de datos personales para finalidades distintas a las expresamente señaladas en este aviso de privacidad, ni realizará transferencias de datos personales a otros responsables, de carácter público o privado, salvo aquéllas que sean estrictamente necesarias para atender requerimientos de información de una autoridad competente, que estén debidamente fundados y motivados, o bien, cuando se actualice alguno de los supuestos previstos en los artículos 22 y 70 de la LGPDPPSO. Dichas transferencias no requerirán el consentimiento del titular para llevarse a cabo.

VII. Mecanismos y medios disponibles para que el titular, en su caso, pueda manifestar su negativa para el tratamiento de sus datos personales para finalidades y transferencias de datos personales que requieren el consentimiento del titular
En concordancia con lo señalado en el apartado VI, del presente aviso de privacidad, se informa que los datos personales recabados no serán objeto de transferencias que requieran el consentimiento del titular. No obstante, en caso de que el titular tenga alguna duda respecto al tratamiento de sus datos personales, así como a los mecanismos para ejercer sus derechos, puede acudir a la Unidad de Transparencia del IFT, ubicada en Avenida Insurgentes Sur #1143 (Edificio Sede), Piso 8, Colonia Nochebuena, Demarcación Territorial Benito Juárez, Código Postal 03720, Ciudad de México, o bien, enviar un correo electrónico a la siguiente dirección unidad.transparencia@ift.org.mx, e incluso, comunicarse al teléfono 55 5015 4000, extensión 4688.

VIII. Los mecanismos, medios y procedimientos disponibles para ejercer los derechos ARCO (derechos de acceso, rectificación, cancelación y oposición al tratamiento de los datos personales)
Las solicitudes para el ejercicio de los derechos ARCO deberán presentarse ante la Unidad de Transparencia del IFT, a través de escrito libre, formatos, medios electrónicos o cualquier otro medio que establezca el Instituto Nacional de Transparencia, Acceso a la Información y Protección de Datos Personales (en lo sucesivo el "INAI").
El procedimiento se regirá por lo dispuesto en los artículos 48 a 56 de la LGPDPPSO, así como en los numerales 73 al 107 de los Lineamientos Generales, de conformidad con lo siguiente:

a) Los requisitos que debe contener la solicitud para el ejercicio de los derechos ARCO.

- Nombre del titular y su domicilio o cualquier otro medio para recibir notificaciones;
- Los documentos que acrediten la identidad del titular y, en su caso, la personalidad e identidad de su representante;
- De ser posible, el área responsable que trata los datos personales y ante la cual se presenta la solicitud;
- La descripción clara y precisa de los datos personales respecto de los que se busca ejercer alguno de los derechos ARCO;
- La descripción del derecho ARCO que se pretende ejercer, o bien, lo que solicita el titular, y
- Cualquier otro elemento o documento que facilite la localización de los datos personales, en su caso.

b) Los medios a través de los cuales el titular podrá presentar las solicitudes para el ejercicio de los derechos ARCO.
Los medios se encuentran establecidos en el párrafo octavo del artículo 52 de la LGPDPPSO, que señala lo siguiente: Las solicitudes para el ejercicio de los derechos ARCO deberán presentarse ante la Unidad de Transparencia del responsable, que

el titular considere competente, a través de escrito libre, formatos, medios electrónicos o cualquier otro medio que al efecto establezca el INAI.

c) Los formularios, sistemas y otros medios simplificados que, en su caso, el INAI hubiere establecido para facilitar al titular el ejercicio de sus derechos ARCO.

Los formularios que ha desarrollado el INAI para el ejercicio de los derechos ARCO, se encuentran disponibles en su portal de Internet www.inai.org.mx, en la sección "Protección de Datos Personales" / "¿Cómo ejercer el derecho a la protección de datos personales? / "En el sector público" / "Procedimiento para ejercer los derechos ARCO".

d) Los medios habilitados para dar respuesta a las solicitudes para el ejercicio de los derechos ARCO.

De conformidad con lo establecido en el artículo 90 de los Lineamientos Generales, la respuesta adoptada por el responsable podrá ser notificada al titular en su Unidad de Transparencia o en las oficinas que tenga habilitadas para tal efecto, previa acreditación de su identidad y, en su caso, de la identidad y personalidad de su representante de manera presencial, o por la Plataforma Nacional de Transparencia o correo certificado en cuyo caso no procederá la notificación a través de representante para estos dos últimos medios.

e) La modalidad o medios de reproducción de los datos personales.

Según lo dispuesto en el artículo 92 de los Lineamientos Generales, la modalidad o medios de reproducción de los datos personales será a través de consulta directa, en el sitio donde se encuentren, o mediante la expedición de copias simples, copias certificadas, medios magnéticos, ópticos, sonoros, visuales u holográficos, o cualquier otra tecnología que determine el titular.

f) Los plazos establecidos dentro del procedimiento —los cuales no deberán contravenir lo previsto en los artículos 51, 52, 53 y 54 de la LGPDPPSO— son los siguientes:

El responsable deberá establecer procedimientos sencillos que permitan el ejercicio de los derechos ARCO, cuyo plazo de respuesta no deberá exceder de veinte días contados a partir del día siguiente a la recepción de la solicitud.

El plazo referido en el párrafo anterior podrá ser ampliado por una sola vez hasta por diez días cuando así lo justifiquen las circunstancias, y siempre y cuando se le notifique al titular dentro del plazo de respuesta.

En caso de resultar procedente el ejercicio de los derechos ARCO, el responsable deberá hacerlo efectivo en un plazo que no podrá exceder de quince días contados a partir del día siguiente en que se haya notificado la respuesta al titular.

En caso de que la solicitud de protección de datos no satisfaga alguno de los requisitos a que se refiere el párrafo cuarto del artículo 52 de la LGPDPPSO, y el responsable no cuente con elementos para subsanarla, se prevendrá al titular de los datos dentro de los cinco días siguientes a la presentación de la solicitud de ejercicio de los derechos ARCO, por una sola ocasión, para que subsane las omisiones dentro de un plazo de diez días contados a partir del día siguiente al de la notificación. Transcurrido el plazo sin desahogar la prevención se tendrá por no presentada la solicitud de ejercicio de los derechos ARCO.

La prevención tendrá el efecto de interrumpir el plazo que tiene el INAI para resolver la solicitud de ejercicio de los derechos ARCO.

Cuando el responsable no sea competente para atender la solicitud para el ejercicio de los derechos ARCO, deberá hacer del conocimiento del titular dicha situación dentro de los tres días siguientes a la presentación de la solicitud, y en caso de poderlo determinar, orientarlo hacia el responsable competente.

Cuando las disposiciones aplicables a determinados tratamientos de datos personales establezcan un trámite o procedimiento específico para solicitar el ejercicio de los derechos ARCO, el responsable deberá informar al titular sobre la existencia del mismo, en un plazo no mayor a cinco días siguientes a la presentación de la solicitud para el ejercicio de los derechos ARCO, a efecto de que este último decida si ejerce sus derechos a través del trámite específico, o bien, por medio del procedimiento que el responsable haya institucionalizado para la atención de solicitudes para el ejercicio de los derechos ARCO conforme a las disposiciones establecidas en los artículos 48 a 56 de la LGPDPPSO.

En el caso en concreto, se informa que no existe un procedimiento específico para solicitar el ejercicio de los derechos ARCO en relación con los datos personales que son recabados con motivo del cumplimiento de las finalidades informadas en el presente aviso de privacidad.

g) El derecho que tiene el titular de presentar un recurso de revisión ante el INAI en caso de estar inconforme con la respuesta.

El referido derecho se encuentra establecido en los artículos 103 al 116 de la LGPDPPSO, los cuales disponen que el titular, por sí mismo o a través de su representante, podrán interponer un recurso de revisión ante el INAI o la Unidad de Transparencia del responsable que haya conocido de la solicitud para el ejercicio de los derechos ARCO, dentro de un plazo que no podrá exceder de quince días contados a partir del siguiente a la fecha de la notificación de la respuesta.

En caso de que el titular tenga alguna duda respecto al procedimiento para el ejercicio de los derechos ARCO, puede acudir a la Unidad de Transparencia del IFT, ubicada en Avenida Insurgentes Sur #1143 (Edificio Sede), Piso 8, Colonia Nochebuena, Demarcación Territorial Benito Juárez, Código Postal 03720, Ciudad de México, enviar un correo electrónico a la siguiente dirección unidad.transparencia@ift.org.mx o comunicarse al teléfono 55 5015 4000, extensión 4688.

IX. Mecanismos, medios y procedimientos para ejercer el derecho de portabilidad de datos personales ante el IFT.

Respecto al derecho a la portabilidad de datos personales, se informa que ninguna de las categorías y/o datos personales recabados es técnicamente portable, al no actualizar los supuestos a los que hace referencia el artículo 8 de los Lineamientos de Portabilidad[1].

X. El domicilio de la Unidad de Transparencia del IFT.

La Unidad de Transparencia del IFT se encuentra ubicada en Avenida Insurgentes Sur #1143 (Edificio Sede), Piso 8, Colonia Nochebuena, Demarcación Territorial Benito Juárez, Código Postal 03720, Ciudad de México, y cuenta con un módulo de

[1] Disponibles en el vínculo electrónico: http://dof.gob.mx/nota_detalle.php?codigo=5512847&fecha=12/02/2018

atención al público en la planta baja del edificio, con un horario laboral de 9:00 a 18:30 horas, de lunes a jueves, y viernes de 9:00 a 15:00 horas, número telefónico 55 5015 4000, extensión 4688.

XI. Los medios a través de los cuales el responsable comunicará a los titulares los cambios al aviso de privacidad.
Todo cambio al Aviso de Privacidad será comunicado a los titulares de datos personales en el micrositio denominado "Avisos de privacidad de los portales pertenecientes al Instituto Federal de Telecomunicaciones", disponible en la dirección electrónica: http://www.ift.org.mx/avisos-de-privacidad
Última actualización: (27/01/2020)

II. Comentarios, opiniones y aportaciones específicos de a persona participante sobre el asunto en consulta pública	
Artículo o apartado	Comentario, opiniones o aportaciones
Comentarios al Anteproyecto de "Acuerdo mediante el cual el Pleno del Instituto Federal de Telecomunicaciones clasifica la banda de frecuencias 5925-7125 MHz como espectro libre y emite las condiciones técnicas de operación de la banda".	
Anteproyecto de acuerdo, Considerando Tercero	**Tercero. Banda de frecuencias 5925-7125 MHz** En el texto del considerando se indica que "*Por ende, la alta demanda de conexiones se incrementó exponencialmente durante el periodo de confinamiento, por lo que es imprescindible llevar a cabo acciones de gestión y planificación del espectro radioeléctrico que permitan responder a esta demanda, ya sea incrementando la cantidad de espectro disponible, o bien optimizando el espectro radioeléctrico para promover su uso eficiente. Por lo anterior, dentro de las acciones de administración del espectro radioeléctrico es pertinente considerar, por un lado, los nuevos desarrollos tecnológicos que permitan incrementar la capacidad de conectividad inalámbrica, y por el otro, los sistemas de radiocomunicaciones que logren hacer un uso más eficiente del espectro radioeléctrico, como aquellos que puedan operar en una misma banda de frecuencias mediante la innovación de los sistemas de radiocomunicaciones para coexistir con otros servicios o aplicaciones sin causar interferencias perjudiciales.*" La DSA concuerda completamente con el Instituto al indicarse el crecimiento en la demanda de conexiones durante el periodo de confinamiento y en este sentido, la importancia de buscar incrementar la capacidad de conectividad y específicamente cree que crucial atender la demanda de banda ancha fija. El crecimiento del tráfico de Internet de acceso fijo y la mayor demanda de descarga de tráfico de redes móviles en redes Wi-Fi (*Offload*) requieren que se incremente la capacidad de las redes de radio de acceso local, como bien lo propone el IFT, destinándoles los 1200 MHz de espectro adicional en la banda de 5925-7125 MHz. A manera de referencia, con respecto al tráfico de las redes fijas, la empresa Assia elaboró un estudio con datos reales de mediciones en Europa, Estados Unidos y Canadá sobre el volumen del tráfico de redes Wi-Fi en espectro libre en las bandas de 2.4 y 5 GHz, su latencia y con indicaciones sobre la intensidad en el uso del espectro (medida a través de las variables de interferencia y congestión)[2]. En particular, el reporte sugiere que: (i) el tráfico de Wi-Fi en estos países se duplica aproximadamente cada dos o tres años, de acuerdo con las tendencias históricas; (ii) mayores incrementos en la intensidad de uso del espectro llevarían a degradación de la calidad de la experiencia para los usuarios. De acuerdo a los datos analizados, es razonable asumir que el tráfico de Wi-Fi en banda media continuará creciendo de acuerdo a los históricos y que para el año 2026 el tráfico de Wi-fi en banda media estará distribuido igualmente entre las bandas de 2.4, 5 y 6 GHz. Bajo estos supuestos, es posible estimar el impacto de la reciente decisión de Estados Unidos, Canadá y Europa sobre la apertura de la banda de 6 GHz para uso libre, es decir, analizar cuándo es probable que se llegue a la misma intensidad actual del uso del espectro, teniendo en cuenta el espectro adicional disponible. Tal análisis sugiere que: (i)

[2] El estudio se encuentra disponible en la página Web de la DSA: http://dynamicspectrumalliance.org/wp-content/uploads/2021/06/ASSIA-DSA-Summit-Presentation-v7.8.pdf

	los reguladores de Estados Unidos y Canadá adoptaron una decisión en la banda de 6 GHz que asegura suficiente disponibilidad de espectro para Wi-Fi (1200 MHz) en los próximos 5 años; (ii) los reguladores europeos adoptaron una decisión en la banda de 6 GHz que asegura suficiente capacidad de espectro de Wi-Fi (480 MHz) para los próximos 2 años. En este sentido, la clasificación de la banda de frecuencias 5925-7125 MHz como espectro libre en México, constata la visión de largo plazo del IFT, dejando las bases no solo para Wi-Fi 6E sino también para la adopción temprana de Wi-Fi 7 en el país.
Anteproyecto de acuerdo, Considerando Tercero	**Tercero. Banda de frecuencias 5925-7125 MHz** Se solicita incluir que para las Américas, es decir la región 2 de la UIT, no hay ningún punto de la Agenda de la Conferencia Mundial de Radiocomunicaciones de 2023 relacionado con la banda 5925-7025 MHz.
Anteproyecto de acuerdo, Considerando Tercero	**Tercero. Banda de frecuencias 5925-7125 MHz** La información recopilada por el Instituto en este considerando con respecto al panorama y actividad internacional es clara y precisa. Hay un rápido avance a nivel internacional, permitiendo un uso libre de la banda en cada vez más países, lo cual se evidencia porque solo durante el tiempo en que ha estado publicada la consulta en México, es han tenido numerosas nuevas consultas y decisiones a nivel internacional. En Arabia Saudita la *Communications and Information Technology Commission* (CITC), que determinó[3] hacer disponible la banda de frecuencias 5925-7125 MHz durante el segundo semestre de 2021, realizó una consulta pública para determinar las condiciones técnicas y de operación en la banda, esta consulta pública con los parámetros técnicos de operación en la banda ya fue realizada[4]. Otros países como Australia[5] y Nueva Zelanda[6] realizaron consultas públicas sobre el futuro de la banda de 6 GHz. La Comisión Europea adoptó la decisión sobre el uso armonizado del 480 MHz de espectro en la banda de frecuencia de 6 GHz para redes Wi-Fi,[7] Alemania adoptó la decisión[8] y Noruega, Bélgica y Francia han realizado o tienen en curso consultas públicas al respecto.
Anteproyecto de acuerdo, Considerando Cuarto	**Cuarto. Prospectiva de la banda de frecuencias 5925-7125 MHz.** En esta sección se indica que "*diversos organismos internacionales han llevado a cabo una serie de estudios tomando en consideración normas y recomendaciones de organismos internacionales, así como las características de operación de las WAS/RLAN. Estos estudios exponen que, con base en los supuestos utilizados, la coexistencia de las WAS/RLAN podrían coexistir con los distintos servicios que actualmente operan en la banda de frecuencias 5925-7125 MHz*". Al respecto se mencionan como referencias el Reporte 302 de la ECC de 2019, el reporte 316 de la ECC de 2020, y el Reporte de la decisión de la FCC respecto a la banda de 6 GHz publicado por la FCC el año pasado. La DSA ha realizado estudios de coexistencia específicos para México y en particular adicional a los comentarios enviados, respetuosamente nos permitimos adjuntar a esta contribución una versión actualizada del estudio de coexistencia específico para el caso mexicano, solicitado a la empresa RKF y titulado "*Frequency Sharing for Radio Local Area Networks in the 6 GHz Band (Version 2.0)*". Este estudio responde a la presente consulta pública y considera por separado los tres tipos diferentes de dispositivos RLAN: • Sistemas de baja potencia (LPI por sus siglas en inglés)

[3] Communications and Information Technology Commission, 2021. Spectrum Outlook for Commercial and Innovative Use 2021- 2023 Consultable en: https://www.citc.gov.sa/en/mediacenter/pressreleases/PublishingImages/Pages/2021033001/Spectrum%20Outlook%20for%20Commercial%20and%20Innovative%20Use%202021-2023.pdf

[4] Detalles sobre la consulta en: https://www.citc.gov.sa/en/new/publicConsultation/Pages/144207.aspx

[5] Detalles sobre la consulta en: https://www.acma.gov.au/consultations/2021-04/rlan-use-5-ghz-and-6-ghz-bands-consultation-122021

[6] Detalles sobre la consulta en: https://www.rsm.govt.nz/projects-and-auctions/consultations/planning-for-wlan-use-in-the-6-ghz-band/

[7] Ver: https://digital-strategy.ec.europa.eu/en/library/6ghz-harmonisation-decision-more-spectrum-available-better-and-faster-wi-fi

[8] https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Allgemeines/Presse/Pressemitteilungen/2021/20210714_WLAN6GHz.pdf?__blob=publicationFile&v=3

	• Sistemas de muy baja potencia (VLP por sus siglas en ingles) • Sistemas de potencia estándar (SP por sus siglas en inglés) Con el fin de identificar si el uso de estos sistemas en la banda de 5925-7125 MHz es compatibles con los servicios existentes en la banda. Para ayudar a responder esta pregunta, *RKF Engineering Solutions, LLC* (RKF), analizó el impacto potencial de las RLAN en tres tipos de usuarios titulares en la banda: servicio fijo por satélite (SFS), servicio fijo (SF) y servicio móvil por satélite (SMS). Como se indica en los documentos de referencia de esta consulta, en México la banda de 6 GHz es compartida principalmente por dos servicios: enlaces ascendentes del FSS y enlaces de microondas fijos (SF). Además, se consideró un *gateway* del SMS ubicado en único sitio en México. La construcción está en marcha para establecer un nuevo sitio de *gateway* en una nueva ubicación fuera de la Ciudad de México. Como lo reconoce el IFT en su documento de referencia, las tres clases de RLAN identificadas se basan en reglas que han sido propuestas por otras autoridades reguladoras, incluidas la Comisión Federal de Comunicaciones de Estados Unidos, Ofcom en el Reino Unido y el Comité de Comunicaciones Electrónicas (ECC) de la Conferencia Europea de Administraciones de Correos y Telecomunicaciones (CEPT). Las especificaciones técnicas de estas clases de dispositivos están destinadas a permitir la coexistencia entre las RLAN y los usuarios titulares de la banda, incluidos los enlaces de servicio fijo (SF), el enlace ascendente por satélite fijo (SFS) y el enlace descendente (*feeder downlink*) del SMS. El estudio hecho por RKF analizó una serie de dispositivos RLAN de transmisión instantánea en simulaciones Monte-Carlo para comprender el riesgo de interferencia en las operaciones del SFS y SF en México. Finalmente, el estudio examinó el riesgo de interferencia en el enlace descendente del *gateway* del SMS desde cada clase (y número total) de dispositivos RLAN que operan dentro de los 150 km del nuevo sitio del *gateway* del SMS. Este estudio utilizó datos basados en la densidad de población en México, así como patrones de uso de RLAN proyectados por consumidores y empresas en términos de tiempo de uso y ubicación (interiores/ exteriores). Además, el estudio tuvo en cuenta el impacto de las pérdidas corporales, el uso en interiores y la distribución de canales y anchos de banda de los dispositivos RLAN en la coexistencia. El análisis mostró que el funcionamiento de dispositivos RLAN en México en toda la banda de 6 GHz no causará interferencias perjudiciales para el SFS, los operadores establecidos del SF, ni para la antena de la estación terrena en el sitio del Gateway del SMS.
Anteproyecto de acuerdo, Considerando Cuarto	**Cuarto. Prospectiva de la banda de frecuencias 5925-7125 MHz.** En esta sección se indica que "*derivado de todo lo anterior, el uso de la banda de frecuencias 5925-7125 MHz para la implementación de redes WAS/RLAN bajo la modalidad de espectro libre, habilitaría un mayor número de canales para las conexiones entre los usuarios y los puntos de acceso de las redes WAS/RLAN, lo que se traduce en mayor velocidad y mayor rendimiento.* *Estas acciones atenderían la creciente demanda de acceso a Internet por medio de tecnologías inalámbricas de última generación que ayudaría a reducir la congestión de las redes WAS/RLAN causada por un gran número de dispositivos conectados al mismo tiempo. Asimismo, se promovería el desarrollo de comunicaciones inalámbricas por medio de redes WAS/RLAN, lo que permitiría contribuir a disminuir la brecha digital en México. De igual manera, al hacer disponible espectro radioeléctrico adicional bajo la modalidad de espectro libre se coadyuvaría a cumplir con las necesidades de conectividad en el país, como por ejemplo, conexión en plazas públicas, centros de salud, hospitales, escuelas y espacios comunitarios, y potencialmente incentivar el desarrollo de comunicaciones inalámbricas en zonas desatendidas y se coadyuvaría a combatir la marginación y la pobreza para la integración de las zonas deprimidas a las actividades productivas*". La DSA está completamente de acuerdo con estas consideraciones, el uso de la banda de frecuencias 5925-7125 MHz para la implementación de redes WAS/RLAN bajo la modalidad de espectro libre, habilita el uso de nuevas tecnologías como por ejemplo Wi-Fi 6E, que tiene importantes ventajas como la posibilidad de soportar más clientes en ambientes densos, mayor eficiencia, flexibilidad, escalabilidad y seguridad en las redes,

	además de maximizar el uso eficiente del espectro y las posibilidades de conectividad inalámbrica de banda ancha a bajo costo, protegiendo los servicios incumbentes que operan en la banda y sin limitar sus posibilidades de crecimiento a futuro. El uso eficiente de la banda es evidente al permitir que los asignatarios de la banda que hacen uso del espectro hoy en día sigan operando y creciendo y al mismo tiempo permitiendo que millones de mexicanos se beneficien de un mejor Wi-Fi. Con respecto a la brecha digital, en el estudio económico titulado "*Estimación del valor económico del uso no licenciado de la banda de 6 GHz en México*"[9] realizado por *Telecom Advisory Services* LLC, se encuentra que el uso libre de la banda de 6 GHz contribuye para reducir la brecha digital de México. La adopción de Internet en el país es estimada en 71.58%[10], mientras que la penetración de usuarios únicos de banda ancha móvil alcanza 59.42%[11], y la banda ancha fija llega a 56% de hogares. Como es de esperar, la población que no ha adoptado banda ancha está concentrada en los sectores más vulnerables de la población urbana y las zonas rurales. Según el estudio, el uso de espectro no licenciado ya contribuye a la disminución de la brecha digital: • Los proveedores de acceso inalámbrico a Internet (denominados WISP, por sus siglas en inglés) operan principalmente en zonas rurales sirviendo a 80,000 hogares[12]; • Los puntos de acceso gratuitos a Wi-Fi permiten a 800,000 mexicanos acceder a Internet; • Los sitios públicos de Wi-Fi representan para muchos mexicanos la única manera para conectarse a Internet. Al 2020 se estimaba que existen unos 44,000 puntos de atención de Internet para Tod@s, donde principalmente se benefician comunidades con menos de 250 habitantes. Estos sitios de acceso son muy relevantes en México, ya que en el año 2019 más de 15,000,000 de mexicanos han accedido a un computador desde sitios públicos[13]. Todas estas áreas se beneficiarán inmediatamente de una designación de la banda de 6 GHz para uso no licenciado, aumentando la capacidad y velocidad de descarga en los puntos de acceso. En contrapartida, una designación del espectro de 6 GHz para uso de los operadores de IMT no resultará en ninguna contribución positiva a la reducción de la brecha digital. Según los autores del estudio, el acceso inalámbrico fijo de 5G (en ingles, *Fixed Wireless Access*) no tendrá impacto alguno tanto en las zonas rurales como en la provisión de servicio a la población vulnerable debido a los elevados costos de despliegue rural y a las tarifas del servicio. El despliegue de una red nacional 5G en México ha sido estimado a requerir una inversión de US$ 37.41 mil millones, de los cuales US$ 24.55 mil millones deberían ser destinados a zonas rurales.[14] Considerando que la inversión de capital anual de operadores celulares mexicanos no excederá US$ 2.70 mil millones para los próximos cinco años[15], se requeriría un aumento de la inversión anual de más de 170% para alcanzar una cobertura rural, un objetivo imposible de realizar. A esta meta inalcanzable, se debe sumar la barrera de asequibilidad en el precio de acceso del servicio 5G. Si de

[9] Este estudio usa de manera indistinta los términos de "espectro no licenciado" y "espectro libre". Se puede consultar en línea en el enlace: http://dynamicspectrumalliance.org/wp-content/uploads/2021/02/Valor-economico-de-la-banda-de-6-GHz-en-Mexico.pdf
[10] Extrapolación al 2020 de datos del ITU data.
[11] GSMA Intelligence (2020).
[12] Encuesta de Wisp.MX realizada en el marco de este estudio.
[13] INEGI. Encuesta Nacional sobre Disponibilidad y Uso de TIC en Hogares (ENDUTIH).
[14] Metodología de estimación originalmente presentada en Katz, R. and Cabello, S. (2019). US$300 billion for Latin America's GDP by expanding mobile connectivity into 5G. retrieved in: https://www.ericsson.com/en/blog/2019/11/expansive-mobile-networks-to-drive-economic-growth-in-latam. Inversión sin incluir costo de adquisición de espectro.
[15] Fuente: GSMA Intelligence, promedio 2021-2025.

	reducir la brecha digital en México se trata, la designación de la banda de 6 GHz para uso libre es clave. Además, la DSA cree que el tiempo no podría ser más crítico para que el Instituto autorice el uso libre del espectro en toda la banda de 6 GHz. La experiencia de los últimos meses en el que el mundo se ha estado enfrentando al COVID-19 ha demostrado la importancia crítica de Wi-Fi como parte de la infraestructura capaz de mitigar los efectos económicos y sociales de la pandemia.[16] El confinamiento en hogares ha puesto de manifiesto la importancia de la tecnología para apoyar la educación a distancia, el teletrabajo y la telemedicina. La demanda de acceso a Internet de banda ancha asequible ha aumentado sustancialmente y en este contexto, el aumento exponencial del tráfico de las telecomunicaciones en el hogar ha impactado el uso de Wi-Fi. Por ejemplo, el porcentaje de tiempo que los usuarios de smartphone están conectados a Internet a través de Wi-Fi en México ha alcanzado el 64%.[17] En lugares donde puede haber varios dispositivos inalámbricos que comparten el ancho de banda de una conexión de Internet en una casa o negocio, la congestión de Wi-Fi es una preocupación. Para cada usuario, no es solo la velocidad del acceso a Internet en el hogar o la empresa lo que importa, sino también la velocidad de Internet de la conexión inalámbrica desde el punto de acceso Wi-Fi a su dispositivo. En este sentido es importante que se aumente la capacidad y se habilite el uso de espectro en otras bandas no licenciadas, como la de 6 GHz.[18]
Anteproyecto de acuerdo, Primero	*Primero.-Se clasifica la banda de frecuencias 5925-7125 MHz como espectro libre para su uso por redes WAS/RLAN, en términos de lo previsto en el Considerando Sexto del presente Acuerdo y de las condiciones técnicas de operación, mismas que se acompañan como Anexo Único al presente Acuerdo.* La DSA aplaude la decisión del IFT de clasificar la banda de frecuencias 5925-7125 MHz como espectro libre para su uso por redes WAS/RLAN en términos de lo previsto en el Considerando Sexto del Acuerdo Que se encuentra en consulta pública y de las condiciones técnicas de operación mismas que se acompañan como Anexo Único del mismo. La decisión del IFT es oportuna para impulsar el uso eficiente del espectro en la banda de 5925-7125 MHz garantizando la coexistencia con los servicios que actualmente operan en esta banda de frecuencias a título primario.
Anteproyecto de acuerdo, Quinto	*Quinto.- Se instruye a la Unidad de Espectro Radioeléctrico a continuar con el análisis y estudio de la implementación de redes WAS/RLAN en exteriores con potencia estándar y el posible uso de un sistema de coordinación automática de frecuencias en segmentos específicos de la banda 5925 – 7125 MHz.* La DSA coincide con el IFT en la necesidad de continuar con el estudio para el uso libre de la banda 5925-7125 MHz en exteriores con el uso de sistemas de coordinación automática de frecuencias (AFC). Lo anterior, en virtud de mantener la protección a los servicios a título primarios que operan en esta banda de frecuencias.
Anexo único, numeral 2.1	*Sistemas de baja potencia que operen bajo la modalidad de espectro libre* La DSA encuentra que los valores propuestos son adecuados. De acuerdo al estudio de RKF los valores son adecuados para proteger a los servicios incumbentes en la banda. Al respecto la DSA apoya totalmente la decisión del IFT de permitir la operación de Sistemas de Baja Potencia bajo la modalidad de espectro libre en la banda 5925-7125 MHz y que dicha operación se limite para operar únicamente en interiores. Sin duda, este tipo de operación contribuirá a ofrecer una mayor calidad en el servicio en los hogares y en las oficinas, entre otros lugares, lo que genera un claro beneficio social,

[16] Con respecto a la importancia de las telecomunicaciones para mitigar el impacto negativo de las pandemias, ver Katz, R.; Jung, J. and Callorda, F. (2020a). "Can digitization mitigate the economic damage of a pandemic? Evidence from SARS". Telecommunications Policy 44, 102044.

[17] Khatri, H. and Fenwick, S. (2020). Analyzing mobile experience during the coronavirus pandemic: Time on Wi-Fi. Opensignal (March 30).

[18] Para más referencia, consultar Katz, R.; Jung, J. and Callorda, F. (2020b). COVID-19 and the economic value of Wi-Fi. New York: Telecom Advisory Services.

	promoviendo acciones como el teletrabajo, la educación a distancia y el entretenimiento, entre otras actividades. El valor propuesto por el IFT para los Puntos de acceso y Puntos de acceso subordinados de DEP <= 5 dBm en cualquier ancho de banda de 1 MHz es un primer paso consistente con las decisiones de otros reguladores de la región como son los Estados Unidos de América, Canadá y Brasil, por lo que con ello impulsará la generación de economías de escala a nivel regional. En este sentido apoyamos esta importante propuesta. Sin perjuicio de lo señalado, es conveniente considerar que esta tecnología y su experiencia de uso se encuentra en sus primeras etapas por lo que es necesario considerar aspectos de implementación práctica que permitan generar el máximo beneficio a las personas que lo utilicen, en especial en los hogares. En este sentido, es de esperar que el valor de DEP 8 dBm/MHz sea más adecuado para poder lograr una cobertura de todo el espacio necesario a servir en un hogar unifamiliar con menos dispositivos. La FCC indica que los valores de DEP de 8 dBm/MHz serían suficientes para reducir la probabilidad de interferencia, pero que adoptaron el valor de 5 dBm/MHz para el caso particular de reducir la probabilidad de interferencia por parte de los dispositivos de interiores de espectro libre hacia las antenas exteriores de los camiones utilizados para la recopilación de noticias en campo (news gathering) del servicio móvil. Como parte del mismo documento, en la sección IV del mismo Further Notice of Proposed Rulemaking, párrafo 232, la FCC ha solicitado comentarios para ampliar el uso de dispositivos de espectro libre de baja potencia en interiores, para lo cual pone a consulta el incrementar la DEP de 5 dBm/MHz a 8 dBm/MHz. Un incremento de 5 dBm/MHz a 8 dBm/MHz sería viable pues existen las condiciones para la operación de dispositivos de espectro libre de baja potencia que operen en la banda 5925-7125 MHz para garantizar la operación libre de interferencias perjudiciales a los servicios a título primario.
Anexo único, numeral 2.2	*Sistemas de muy baja potencia que operen bajo la modalidad de espectro libre* La DSA aplaude la decisión del IFT de permitir la operación de Sistemas de Muy Baja Potencia bajo la modalidad de espectro libre en la banda 5925-7125 MHz. Este tipo de sistemas marcan una nueva etapa para el ecosistema de Wi-Fi y, el desarrollo de nuevas aplicaciones y dispositivos de diversa índole, destacando el uso de aplicaciones de realidad virtual y realidad aumentada, que tienen el potencial de incidir en el bienestar de las personas desde el entretenimiento hasta el trabajo, la educación y la salud, ente otros campos. La DSA encuentra que los valores propuestos son adecuados, sin embargo recomienda muy respetuosamente que el IFT considere valores de PIRE superiores de hasta 17 dB para canales de 320 MHz de ancho de banda.
Nota: añadir cuantas filas considere necesarias.	

III. Comentarios, opiniones y aportaciones generales de la persona participante sobre el asunto en consulta pública
Nota: añadir cuantas filas considere necesarias.

Frequency Sharing for Radio Local Area Networks in the 6 GHz Band (Version 2.0)

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Prepared by:

RKF Engineering Solutions, LLC
7500 Old Georgetown Road
Bethesda, MD

Prepared for:

Instituto Federal de Telecomunicaciones - Mexico

1 Table of Contents

1.0 Executive Summary

This study responds to the Consultation issued by the Institute Federal de Telecomunicaciones (IFT) regarding the prospective use of the 5.925 to 7.125 GHz band ("6 GHz band").[1] The IFT raises questions about the potential use of the band by license-exempt devices, such as Radio Local Area Networks (RLANs).[2] The Consultation asks questions about three different types of RLANs (collectively referred to as RLANs in this report):

- Low Power Indoor (LPI)
- Standard Power (indoor/outdoor) with Automated Frequency Coordination (AFC)
- Very Low Power (VLP) (indoor/outdoor)

The Consultation also asks questions regarding whether such RLAN use is compatible with existing incumbent services in the band.

To assist in answering these questions, RKF Engineering Solutions, LLC (RKF), analyzed the potential impact of license-exempt RLANs on three types of incumbent users in the band: Fixed Satellite Service (FSS), Fixed Service (FS), and Mobile Satellite Service (MSS). In Mexico, the 6 GHz band is shared primarily by two services: FSS uplinks[3] and fixed microwave (Fixed Service or FS) links. Additionally, there had been a single MSS feeder downlink site in Mexico that was taken off-line a few years ago. Construction is underway to establish a new MSS feeder downlink "gateway" site at a new location outside of Mexico City.

As IFT recognizes in its Reference Document,[4] the three identified classes of RLANs are based on rules that have been proposed by other regulatory authorities, including the US Federal Communications Commission, Ofcom in the United Kingdom and by the Electronic Communications Committee (ECC) of the European Conference of Postal and Telecommunications Administrations (CEPT). The technical specifications of these device classes are intended to allow for coexistence between RLANs and incumbent users of the band, including Fixed Service links (FS),fixed satellite uplink (FSS), and the Mobile Satellite Service MSS feeder downlink.

This study examines the coexistence of RLAN usage in the 6 GHz band and incumbent FSS satellite uplink services in Mexico. In addition, this study examines the impact of RLAN usage for a subset of FS links in Mexico City. This study assumes a number of instantaneously transmitting RLAN devices in Monte-Carlo simulations to understand the interference risk to FSS and FS operations in Mexico. Finally, the study examines the interference risk to the MSS feeder downlink from each class (and total number) of RLAN devices operating within 150 km from the new MSS gateway site.

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[1] Public Consultation of Integration of the "Frequency Band Questionnaire 5925-7125 MHz," Institute Federal de Telecomunicaciones (5 November 2020) http://www.ift.org.mx/industria/consultas-publicas/consulta-publica-de-integracion-del-cuestionario-sobre-la-banda-de-frecuencias-5925-7125-mhz ("Consultation").

[2] RLAN is a generic term used to describe a device that provides local area network connections between various electronic devices. While Wi-Fi is one type of RLAN, this study applies to other RLANs with Unlicensed National Information Infrastructure (U-NII) operating characteristics.

[3] Paired with FSS downlinks in 3.4-4.2 GHz band.

[4] IFT Reference Document, Frequency Band 5925-7125 MHz, October 2020 *available at* http://www.ift.org.mx/industria/consultas-publicas/consulta-publica-de-integracion-del-cuestionario-sobre-la-banda-de-frecuencias-5925-7125-mhz ("IFT Reference Document").

This study used data based on the population density in Mexico, as well as projected consumer and business RLAN usage patterns in terms of the time of use and the location (indoor/outdoor). In addition, the study accounted for the impact of body loss, indoor use, and the bandwidth and channel distribution of the RLAN devices on coexistence.

The analysis showed that RLAN operation in Mexico in the entire 6 GHz band will not cause harmful interference to FSS or FS incumbents, as well as the earth station antenna at the MSS gateway site.

1.1 Fixed Satellite Service (FSS)

In the 6 GHz uplink band, the aggregate I/N into a number of satellite uplink beams was computed using Monte-Carlo simulations with random RLAN deployments and available satellite G/T contours. The RLANs were deployed in Mexico as well as all other countries within each satellite's view. For a conservative analysis, satellite beams with higher G/T over Mexico or bigger coverage of areas had been chosen. Information on the FSS filings was extracted from the International Telecommunication Union (ITU) Radiocommunication Bureau (BR) International Frequency Information Circular (IFIC) Space Services database.

The analysis has been applied to a satellite channel plan assuming 36 MHz channels in 40 MHz occupied bandwidth on two polarizations. Each channel on each satellite has been subject to 10 independent RLAN deployments of a Monte Carlo simulation.

Simulations show that in all cases studied, the I/N for all satellites in all channels and simulation iterations is less than -26.92 dB. It can be concluded that a deployment of RLANs in the field of view of the affected satellites will not impact the operation of the Mexican FSS uplinks in the 6 GHz band.

In conclusion, RLANs in the three device classes operating over a 20, 40, 80, or 160 MHz channel bandwidth do not cause harmful interference to an FSS uplink.

1.2 Fixed Service (FS)

Monte-Carlo simulations were performed with random RLAN deployments to understand the interference risk to FS operations in Mexico. The simulation consisted of 100,000 RLAN deployment iterations to gather stable, long-term interference statistics at each of 27 FS sites around Mexico City.

Statistics were gathered at each FS, on the occurrence probabilities for both I/N > -6 dB and 0 dB. Because these metrics do not fully describe the interference risk, an additional metric, increased FS unavailability due to RLAN interference, was used to assess degradation in FS performance. This analysis assumed a typical FS design target of 99.999% availability (unavailability=0.001% corresponding to 5.3 minutes/year). Results were compared to a target increase in unavailability of less than 10% (availability with interference >99.9989%) sufficient to allow continued robustness of FS links while also allowing the new RLAN service. Sensitivity to a 1% increase in unavailability was also considered.

The I/N > -6 dB and 0 dB average occurrence probability of a single FS was 0.209% and 0.035% respectively for the Baseline Simulations.

For the FS availability analysis, the increase in unavailability due to RLAN interference of the 27 FS links was further analyzed in two steps. In the first step, a representative link margin required to meet the target availability was calculated without considering the specific operational parameters of each FS link. This simplified analysis allowed a large number of links to be processed. In the second step, if the simplified analysis indicated an FS link did not meet the target 10% unavailability increase, individual FS operational parameters were analyzed to determine the actual increase in unavailability. This analysis provided a realistic assessment of the long-term impact of the RLAN interference on FS stations and showed **all 27 links met the 10% increase in unavailability target as well as the 1% increase in unavailability sensitivity threshold.**

In conclusion, our analysis showed that RLAN operation within the parameters of the three device classes described in this report, at a variety of channel sizes, will not cause harmful interference to FS stations. In addition, sensitivity analyses on parameters including bandwidth, number of active devices, and EIRP indicated that in all cases the probability of an I/N > -6 dB occurrence was low and the increase in unavailability was sufficiently low to allow continued robustness of FS links.

1.3 Mobile Satellite Service (MSS) Gateway

A Monte-Carlo Simulation was performed using 100,000 iterations of randomly deployed RLANs to calculate the aggregate signal received by the MSS earth station antenna from each class of RLANs within 150 km of the new MSS gateway location.

The geo-coordinates and operating characteristics of the MSS downlink receiving earth station, located in an isolated valley west of Mexico City, were taken from the MSS gateway operator's license application. At the new MSS gateway site under construction, a single earth station antenna was selected. The MSS constellation's movement as viewed from the MSS receiving station was simulated over time. For a randomly selected moment, one of the satellites in view above the radio horizon was chosen. There were 20,000 iterations of the MSS constellation's movement. In each simulation iteration, the pointing direction of the earth station antenna was chosen randomly. A cumulative distribution function (CDF) of the earth station antenna elevation angle was generated.

The simulation examined the effect on the (victim) earth station antenna of the randomly selected pointing angles and RLAN placements over the large number of iterations. The simulation generated separate CDFs for LPI, Standard Power, VLP, and total RLAN devices for I/N > -6 dB and I/N > -12.2 dB. The results show that the cumulative probabilities of an I/N > -6 and I/N > -12.2 are very low for all three RLAN classes and well within the expected range for total RLANs. The CDF for an I/N > - 6 are 0.031%, 0.049%, and 0.003% respectively for Standard Power, LPI and VLP devices. For an I/N > -12.2, the CDF values increase to 0.070%, 0.146% and 0.006% respectively for Standard Power, LPI, and VLP devices. The conclusion is that the risk of harmful interference to the MSS earth station receiver is extremely low.

2 Introduction

Devices that employ Wi-Fi and other unlicensed standards have become indispensable for providing low-cost wireless connectivity in countless products used by Mexican consumers. License-exempt technologies are a critical element in delivering broadband connectivity to consumers and businesses. Wi-Fi is needed to connect all devices in a household or business to a wired or wireless broadband connection. As consumers rely on more devices, reliable and fast Wi-Fi connectivity has become essential. However, despite the increasing reliance on license-exempt technology, and the enormous growth in traffic demands being placed on the technology globally, the spectrum allocated to Wi-Fi use remains limited to the 2.4 GHz and 5 GHz bands as it has for many years.

The latest Wi-Fi technology—designed for speed, low latency and to optimize use by many devices in the same location—uses much wider channelization to meet the far more intensive broadband needs of consumers and businesses alike. For example, the latest generation of Wi-Fi technology, Wi-Fi 6, can utilize radio channels as broad as 80 or 160 megahertz, and a future generation of Wi-Fi technology that is already in development will utilize channels of 320 megahertz.[5]

For these reasons, on April 23, 2020, the Federal Communications Committee in the United States (the FCC) adopted rules[6] that made 1200 MHz of spectrum available in the 6 GHz band (5.925-7.125 GHz) for license-exempt use. These new rules will expand license-exempt broadband operations that promise to bring a wide range of innovative wireless applications to consumers while protecting incumbent users in the band. As has occurred with Wi-Fi in the 2.4 GHz and 5 GHz bands, it is expected that the rules adopted for 6 GHz unlicensed devices will foster the expansion of Wi-Fi hotspot networks to provide consumers access to even higher speed data connections and growth in the Internet-of-things (IoT) industry—connecting appliances, machines, meters, wearables, and other consumer electronics, as well as industrial sensors for manufacturing. This capability will quickly become a part of peoples' everyday lives.

In this study, produced in response to the IFT's consultation on the 6 GHz band, RKF used a proven methodology to model a Monte Carlo simulation of coexistence. This methodology was used in the studies submitted before the US FCC.

The study is focused on examining coexistence between the three classes of RLANs (Standard-Power AFC, LPI, and VLP) and the uplink of Mexico's FSS satellites in the 5925-6425 MHz band. To produce results for Mexico, RKF used data based on the population distribution and

[5] "Wi-Fi 6 Certified, Capacity, efficiency, and performance for advanced connectivity," Wi-Fi Alliance, https://www.wi-fi.org/discover-wi-fi/wi-fi-certified-6. There are a number of technological improvements contained in Wi-Fi 6 that make this generation of technology the most spectrally efficient version of Wi-Fi in history, including multi-user MIMO, beamforming, and "target wake time" to improve network efficiency and device battery life. When deployed in 6 GHz, Wi-Fi 6 will be called Wi-Fi 6E.

[6] *See Unlicensed Use of the 6 GHz Band,* Report and Order and Further Notice of Proposed Rulemaking, ET Docket No. 18-295, FCC 20-51 (rel. Apr. 23, 2020) at https://ecfsapi.fcc.gov/file/0424167164769/FCC-20-51A1_Rcd.pdf. ("*6 GHz Report and Order*").

density in Mexico, as well as projected consumer and business RLAN usage patterns in terms of the time of use and the location (indoor/outdoor). In addition, the study accounted for the impact of body loss, indoor use, and the bandwidth and channel distribution of the RLAN devices on coexistence.

RKF obtained Mexico FSS uplink data from BR International Frequency Information Circular (S pace Services) (BR IFIC).

The data for FS links in the vicinity of Mexico City and the MSS gateway were provided by the IFT.

2.1 Background on Three Classes of RLANs

This analysis included the three classes of RLANs recognized by the IFT in its Reference Document.[7] This device class framework that has been established by the FCC[8] as well as the United Kingdom[9] and Europe. [10]

Low Power Indoor: The FCC authorized LPI access points and client devices across the entire 6 GHz band and do not rely on the AFC system for determining the frequencies available for use. These low-power access points will be ideal for connecting devices in homes and businesses, such as smartphones, tablet devices, laptops, and IoT devices, to the Internet. Using these advanced Wi-Fi technologies and wider channels (up to 320 MHz) available in the 6 GHz band, unlicensed devices promise to spur innovations and allow consumers to experience faster internet connections and new applications well beyond what is possible with 2.4 GHz and 5 GHz bands.

Very Low Power portable: The FCC has an active rulemaking proceeding considering VLP portable (indoor/outdoor) devices in the 6 GHz band at 14 dBm EIRP. The United Kingdom adopted this class of RLANs, and Europe is poised to adopt the same.[11] Portable VLP devices will expand innovation even further and will be critical for supporting indoor and outdoor portable use cases such as wearable peripherals including augmented reality/virtual reality as well as in-vehicle applications and other personal-area-network applications.

Standard Power with AFC: The FCC authorized Standard Power with AFC access points but restricted them to operate within the UN-II 5 (5925-6425 MHz) and UN-II 7 (6525-6875 MHz) portions of the band. The AFC system determines the frequencies on which Standard Power access points operate without causing harmful interference to incumbent microwave receivers and then identifies those frequencies as available for use by Standard Power access points.

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[7] IFT Reference Document at 18-31.

[8] *See* 6 GHz Report and Order (adopting low power indoor and standard power with AFC and proposing VLP in its Further Notice of Proposed Rulemaking).

[9] The UK adopted LPI and VLP in the lower 500 MHz of the 6 GHz band. Statement:Improving Spectrum access for wifi—spectrum use in the 5 and 6 GHz bands (24 July 2020) *available at* https://www.ofcom.org.uk/__data/assets/pdf_file/0036/198927/6ghz-statement.pdf

[10] The Electronic Communication Committee approved the ECC Decision 20(01) and the CEPT Report 75 during its plenary meeting 16-20th November 2020. This Decision supports LPI and VLP in the lower 500 MHz of the 6 GHz band.

[11] Cite

2.2 Approach

A detailed nationwide simulation of the interference environment was developed and RKF ensured its simulation was a conservative representation of the interference environment by:

1) Analyzing FSS beams susceptible to highest interference levels. The BR International Frequency Information Circular (Space Services) (BR IFIC) was used to extract the FSS filings;
2) Using the Gridded Population of the World V4 (GPWv4) from NASA's Socioeconomic Data and Applications Center (SEDAC). GPWv4 provides a global composite raster grid of population density at 30 arcsecond resolution (approximately 1 km at the equator) using population estimates for the years 2000, 2005, 2010, 2015 and 2020. This dataset can also be supplemented with national population projections from other sources for intermediate or extrapolated years through linear scaling approximations over administration boundaries. The population of Mexico, as well as the Americas and other areas in the view of the simulated Satellites, in 2025 has been calculated on the basis of the 2018 edition of the UN World Population Prospects;
3) Using realistic but conservative RLAN operating and deployment assumptions as described in Section 3.0. These were based on existing and projected market data, usage, and performance;
4) Using worst case scenarios to represent possible situations;
5) Executing numerous different scenarios with a wide variation of propagation paths and RLAN deployment configurations to ensure statistically significant results. US Census Bureau (USCB) definitions are used to partition the Mexico into urban, suburban, and rural areas and the GWPv4 2025 projected Mexico population density was used to randomly deploy RLANs for each simulation iteration;
6) An I/N of -6 dB was used as a comparison threshold for the FS in this study with the understanding that the analysis in this report is very conservative and did not take into account many factors that would lower the aggregate I/N.
7) The MSS gateway study used I/N values of -6 dB and -12.2 dB as comparison thresholds. Similar to the FS study, the analysis is conservative and did not take into account factors that would lower the aggregate I/N.

Simulation results and sharing studies with FSS uplinks are covered in Section 5.1, FS links in Section 5.2, and the MSS gateway in Section 5.3.

3 RLAN Deployment and Operating Assumptions

This section describes the analysis and methodology for assigning source quantities to the proposed 6 GHz band RLANs and their operating parameters.

3.1 RLAN Deployment Assumptions

3.1.1 Number of Active RLANs and Deployment Distribution

Table 3-1 depicts the parameters and calculations used to develop the numbers of active RLANs. As noted above, this study applies to all RLAN classes below, including but not limited to Wi-Fi Access Points (AP) and stations:

- Indoor (98%):
  - LPI and Standard-Power (88%)[12]
  - VLP (10%)
- Outdoor (2%):
  - Standard-Power (1%)
  - VLP (1%)

At a first level, the deployment of RLANs is assumed to be closely associated with population density, and therefore geographically allocated according to the population distribution in Mexico. The basis of the active device analysis is an estimated Mexico population of 141 million in 2025. As described in Section 3.1.2, we used USCB population density thresholds that determined the percentage of population in urban, suburban, and rural areas across Mexico.

[12] The MSS gateway study will separate out the number of LPI (and LPI clients) and indoor Standard Power (and Standard Power clients) units in order to derive the total number of LPI and Standard Power devices. The total number of indoor versus outdoor devices remains the same.

Table 3-1 - RLAN Active Device Distribution

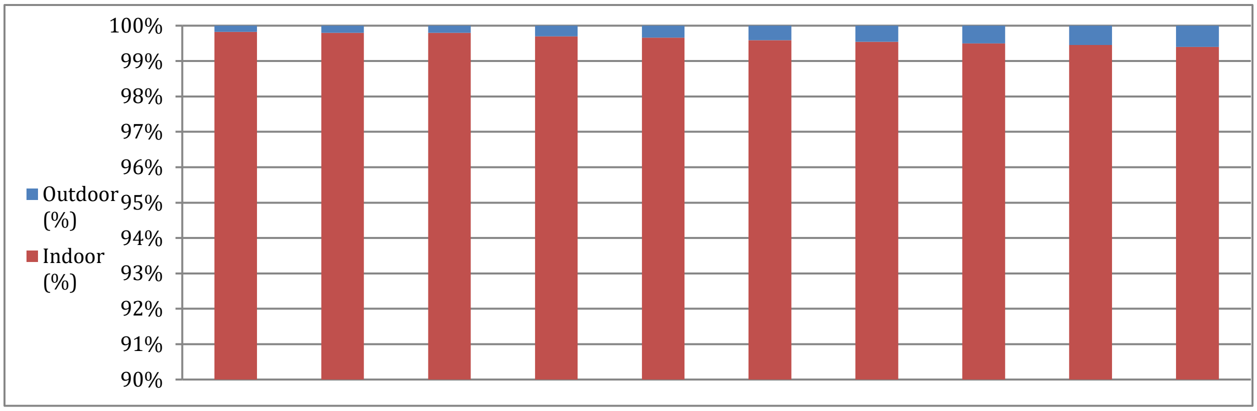
	TOTAL	URBAN			SUBURBAN			RURAL (includes BARREN)		
Population (%)	**100.0000%**	**77.0%**			**3.7%**			**19.3%**		
User Type	**All**	**Corporate**	**Public**	**Home**	**Corporate**	**Public**	**Home**	**Corporate**	**Public**	**Home**
Type (%)	**All**	10	5	85	5	5	90	2	1	97
Device Population	**433,018,636**	33,344,470	16,672,235	283,427,997	790,831	790,831	14,234,951	1,675,150	837,575	81,244,771
High Activity Device Population (% of Total)		10%	10%	10%	10%	10%	10%	10%	10%	10%
Data per device per hour, (MBytes)		1000	500	2000	1000	500	2000	1000	500	2000
Device Rate (Mbps)		2.22	1.11	4.44	2.22	1.11	4.44	2.22	1.11	4.44
Link Speed (Mbps)		1000	1000	1000	1000	1000	1000	1000	1000	1000
Duty Cycle per Device		0.22%	0.11%	0.44%	0.22%	0.11%	0.44%	0.22%	0.11%	0.44%
Instantaneous Number of Transmitting 6 GHz Devices (Subtotal, High Activity)	**178,395**	7,410	1,852	125,968	176	88	6,327	372	93	36,109
Low Activity Device Population (% of Total)		90%	90%	90%	90%	90%	90%	90%	90%	90%
Data per device per hour, (Mbytes)		1	1	1	1	1	1	1	1	1
Device Rate (Mbps)		0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022
Link Speed (Mbps)		1000	1000	1000	1000	1000	1000	1000	1000	1000
Duty Cycle per Device		0.00022%	0.00022%	0.00022%	0.00022%	0.00022%	0.00022%	0.00022%	0.00022%	0.00022%
Instantaneous Number of Transmitting 6 GHz Devices (Subtotal, Low Activity)	**866**	67	33	567	2	2	28	3	2	162
Instantaneous Number of Transmitting 6 GHz Devices (total)	**179,261**	**7,477**	**1,886**	**126,535**	**177**	**89**	**6,355**	**376**	**95**	**36,271**

Assuming an average RLAN device count of 10 per person, the total RLANs in operation over Mexico is estimated to be 1.41 billion in 2025 and the market penetration of 6 GHz capable RLANs is assumed to be 45%. Because 6 GHz capable RLANs are expected to also operate in the 2.4 and 5 GHz bands, and assuming spectrum loading will be even across all the contemplated channels in the unlicensed bands, 68% of 6 GHz enabled RLANs are estimated to be using the 6 GHz band. As shown in the following equation, the resulting number of RLANs connected to a 6 GHz network is 433 million:

Total 6 GHz Attached Devices = Total Population (people) x Devices per Person x Market Penetration x (target 6 GHz Spectrum) / (total 2.4 + 5 + 6 GHz Spectrum) (3-1)

Total 6 GHz Attached Devices = (141,132,000 x 10 x 0.45 x 1200/1760) = 433 Million (3-2)

To estimate indoor versus outdoor deployments, we used Figure 3-2 which depicts the ratio of indoor vs outdoor Wi-Fi AP shipments from 2011 to 2021, including both historical actual shipment figures for Wi-Fi APs through 2016 as well as a forecast for future years. Outdoor unit shipments in 2021 are estimated at 0.6% of all Wi-Fi APs.



Deployment Type	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Indoor APs	99,750.2	112,676.0	123,414.7	122,463.5	140,000.1	147,825.7	159,546.9	171,540.1	182,602.2	189,331.7
Outdoor APs	171.7	229.3	245.5	375	477.1	609	726.8	860.4	1,002.8	1,152.1
Total	99,921.9	112,905.3	123,660.2	122,838.5	140,477.2	148,434.7	160,273.7	172,400.5	183,605.0	190,483.8

Figure 3-1 - Worldwide Indoor vs Outdoor Wi-Fi Shipments. Source: Dell'Oro Group July 2017 Wireless LAN report

While this study considers RLANs generally, a conservative model for outdoor 6 GHz RLANs may consider both Wi-Fi and 3GPP based technologies such as Licensed Assisted Access (LAA) because many small cell deployments are expected to be outdoors. Table 3-2 depicts data from the Small Cell Forum and shows a forecast of 1.5 million outdoor small cells deployed in 2021.[13]

Applying the same 45% market penetration for outdoor small cells that are LAA and 6 GHz-capable, yields figures slightly lower than the outdoor Wi-Fi AP market. The combined forecast of Wi-Fi and small cell outdoor shipments is approximately 1% of total units in 2021. Doubling this figure yields a conservative ratio for indoor vs. outdoor RLANs in all sub-markets of 98% and 2% respectively.[14]

Table 3-2 - Small Cell Forum Forecast for Outdoor Small Cell Shipments (thousands)

	2014	2015	2016	2017	2018	2019	2020	2021	CAGR
Indoor	176	310	794	1,080	1,901	2,946	3,420	3,239	52%
Outdoor	47	78	251	441	937	1,387	1,466	1,596	66%
Total	**223**	**388**	**1,045**	**1,521**	**2,838**	**4,333**	**4,886**	**4,835**	**55%**

For the peak usage analysis (busy hour), an activity level was assigned to represent the amount of data consumed wirelessly. For this analysis, the activity on these RLANs was distributed around two primary modes (i.e., bi-modal):

- "High activity" mode – Typical of RLANs in active use by a person. For this simulation we assumed one device per person, a more conservative model than typical assumptions.

[13] This data is based on a forecast made in 2018.
[14] 5G Americas and Small Cell Forum, *Multi-operator and Neutral Host Small Cells: Drivers, Architectures, Planning and Regulation*, Dec. 2016, http://www.5gamericas.org/files/4914/8193/1104/SCF191_Multi-operator_neutral_host_small_cells.pdf.

- "Low activity" mode – Typical of RLANs making periodic or intermittent transfers of data, such as RLANs connected to the network but not in direct use (idle), or RLANs that make small data transfers typical of "Internet of Things" (IoT) connected devices.

To determine the worst-case time of interference into incumbent systems, busy hours for corporate, public, and home usage were studied. The study assumed that RLAN usage is heaviest during busy hour across Mexico of 7:00 pm – 8:00 pm CDMX. It was assumed that on average every person in Mexico is actively using one RLAN during the busy hour while owning an average of nine other RLANs that were not being actively used. As a result, the percentage of devices in the High activity mode was assumed to be 10% and 90% were assumed to be in the Low activity mode. [15,16]

For devices in the High activity mode, usage was modeled to be 2.0 Gbytes/hour (4.44 Mbps) for the home user, 1 Gbytes/hour (2.22 Mbps) for the corporate user, and 500 Mbytes/hour (1.11 Mbps) for public (hotspot connected) users. For devices in the Low activity mode, usage was modeled to be 1 Mbyte/hour (2.2 kbps).

As a final step in this derivation, the efficiency of high bitrate modulation techniques offered by modern unlicensed wireless technologies is considered. It is expected that new, 6 GHz technology will deliver an average application layer throughput rate of 1 Gbps as achieved in current 5 GHz technology. It is also expected that this capability will be deployed for the types of 6 GHz devices in use during the busy hour for applications like video streaming. Based on the available over-the-air rate of the AP, the data required per device per hour and the required duty cycle can be assigned per device as follows:

Device Duty Cycle (% of available airtime) = Data per Device per Hour (Mbytes) x (8 bits / 3600 secs) / Average Rate (Mbps) *(3-3)*

For example, for the Home Market active device model

Device Duty Cycle = 2000 MBytes x (8/3600) / 1000 Mbps = 0.44 % *(3-4)*

The number of instantaneously active devices included in the model over all of Mexico is the sum of the low and high activity mode devices for all markets (urban, suburban, rural) and environments (corporate, public, home) as follows:

Instantaneous Transmitting Devices = Total Devices Using 6 GHz x Duty Cycle *(3-5)*

Note that the device duty cycle is calculated and assigned for all RLANs in each of the above market types and environments and for both low and high activity mode devices. Table 3-1 shows the resulting input quantities of instantaneous transmitting devices for each of these markets and environments.

[15] ITU document Revision 1 to 5A/TEMP/236, Sharing and compatibility studies of WAS/RLAN in the 5 150-5 250 MHz frequency range, Section 5.1.1.4.2.5, stated busy hour demographic factor was 71%, 64%, and 47% for urban suburban, and rural populations. This simulation assumed 90%.

[16] While the ITU-R Working Party 5A concludes that busy hour participation is 62.7%, this simulation uses 90%. ITU-R, *Annex 22 to Working Party 5A Chairman's Report: Use of Aggregate RLAN Measurements from Airborne and Terrestrial Platforms to Support Studies Under WRC-19 Agenda Item 1.16* (Nov. 16, 2017) at 3, *available at* https://www.itu.int/md/R15-WP5A/new/en (ITU-R 5A/650 (Annex 22)-E).

3.1.2 Population Density

Sharing analysis for this report used an estimated 2025 population density, based on the UN World Population Prospects, to randomly distribute the active RLANs estimated in Section 3.1.1.[17] Population density thresholds, were derived over the contiguous United States (CONUS) by dividing CONUS into 71.2% urban, 9.5% suburban, and 19.3% rural[18] geo areas, based on USCB 2010 percentages. This resulted in population density thresholds that are applied to Mexico's population density grid database per below:

- if population density ≥ people/km^2, it is urban;
- else if 227.30449 people/km^2 ≤ population density < 513.04217 people/km^2, it is suburban;
- else, it is rural.

This resulted in percentages of Mexico population and area in urban, suburban and rural geo-areas per Table 3-3.

The resulting population and area percentages shown in Table 3-1 were used in the simulations to randomly distribute the number of RLANs estimated in Section 3.1.1 for sharing analysis with the existing uplink FSS and FS services, and the future MSS gateway in the 6 GHz band.

As can be seen, approximately 98% of Mexico is rural, which implies that interference will be predominantly concentrated in urban and suburban areas.

Table 3-3 - Population Density in Mexico

	Population (%)	**Area[19] (%)**
Urban	77.0%	1.4%
Suburban	3.7%	0.8%
Rural	19.3%	97.7%[20]

3.2 RLAN Operating Assumptions

To perform a thorough simulation of RLAN sharing of the 6 GHz band, reasonable statistical operating assumptions were developed to account for the myriad possibilities of RLAN use given the deployment models in Section 3.1. As described in that section, we are considering rural, suburban, and urban environments with corporate, public, and home submarkets. Within each of these nine submarkets, key operating parameters that affect the received interference level include RLAN source EIRP, bandwidth and channel usage, and installed height. Because

[17] Socioeconomic Data and Applications Center, *Gridded Population of the World (GPW), v4,* NASA, http://sedac.ciesin.columbia.edu/data/collection/gpw-v4/maps/gallery/search?facets=theme:population (last visited June 27, 2020).

[18] These definitions are consistent with the 2010 Census Bureau classifications (urban clusters, urbanized areas, and rural environments).

[19] The sum of the areas does not add to 100% due to rounding.

[20] 10.6% of the area has zero population.

these operating parameters can vary, statistical assumptions must be derived before they can be used in the simulations.

3.2.1 Distribution of Source LPI and Standard Power with AFC RLAN Power Levels

To develop the statistical LPI and Standard Power with AFC RLAN source power, or EIRP, we looked at typical use cases, RLAN peak power, and busy hour usage weights for LPI and Standard Power with AFC RLANs (referred to "RLANs" in this section). Since RLAN locations and antenna orientations tend to be random and RLANs generally have a wide range of available output power and operating characteristics, randomization of the RLAN source EIRP values is a valid approach for the broad statistical analysis of this report.

As stated in Section 3.1, both indoor and outdoor RLAN installations were randomized based on population density and therefore can be installed anywhere relative to a victim receiving location. In each installation, the orientation of the RLAN antenna is in general not fixed. Therefore, in the analysis we assumed an equal weight assigned to all values in the E-plane pattern. Outdoor RLAN antennas most likely will be oriented such that the omnidirectional pattern is horizontal with respect to the ground at the installation site and, as shown in Figures 3-4 through 3-9, will be designed to limit maximum EIRP to 1 Watt above 30^o in elevation (9 dB higher than currently allowed in U-NII-1 rules). Even though indoor RLAN antennas have similar elevation patterns (E-plane) as outdoor RLANs, an isotropic radiating pattern for all indoor RLANs was used in the simulations to define a worst-case scenario.

Given these basic assumptions, the expected RLAN power levels can be represented by a distribution of power levels. To derive the RLAN source EIRP in the submarkets described in Section 3.1.1, seven typical use cases were used.

- Indoor Enterprise AP, Indoor Consumer AP, and Indoor High-Performance AP
- Indoor/Outdoor Client
- Outdoor High-Power AP, Outdoor Low Power AP

Table 3-4 provides the peak power of these use cases in the elevation patterns (E-plane) depicted in Figure 3-3 through 3-8. For this analysis, the horizontal patterns (H-plane) were assumed to be omnidirectional.

Table 3-4 – Peak Power (EIRP) of Typical LPI and Standard Power with AFC RLAN Use Cases

	Indoor Enterprise AP	**Indoor Consumer AP**	**Indoor High Performance Gaming Router**	**Indoor/Outdoor Client**	**Outdoor High Power AP**	**Outdoor Low Power AP**
	Figure 3-4	*Figure 3-5*	*Figure 3-6*	*Figure 3-7*	*Figure 3-8*	*Figure 3-9*
Conducted Power (dBm)	13.5	12.5	24	12	27	14
Peak Antenna Gain (dBi)	4.1	5.3	5.3	3.5	5.3	5.3
MIMO Gain (dB)	6.0	6.0	6.0	3.0	3.0	4.8
Total Peak EIRP (dBm)	**23.6**	**23.8**	**35.3**	**18.5**	**35.3**	**24.1**

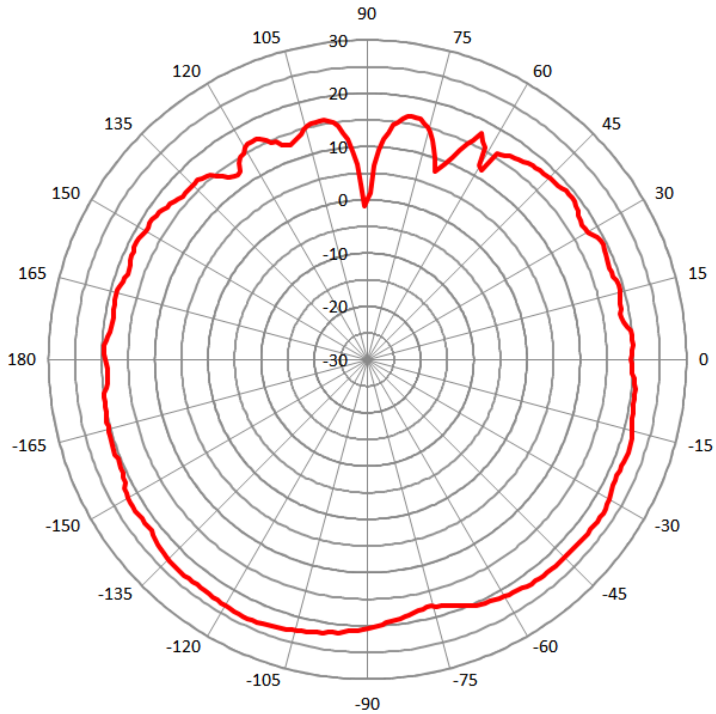


Figure 3-2 - Indoor Enterprise Access Point, Typical Pattern (EIRP)

Indoor Enterprise Access Point EIRP Probability based on E-Plane Directivity	
36 dBm ≤ 30 dBm	0.00%
< 30 dBm ≤ 24 dBm	0.00%
< 24 dBm ≤ 20 dBm	40.17%
< 20 dBm ≤ 17 dBm	34.07%
< 17 dBm ≤ 11 dBm	22.16%
< 11 dBm ≤ 0 dBm	3.32%
< 0 dBm	0.28%
Total	**100.00%**

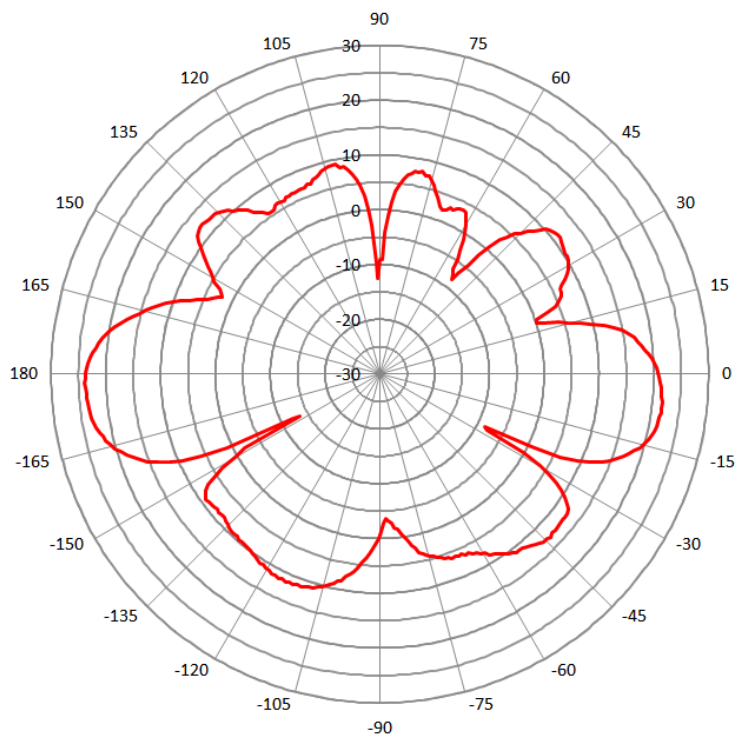


Figure 3-3 - Indoor Consumer Access Point, Typical Pattern (EIRP)

Indoor Consumer Access Point EIRP Probability based on E-Plane Directivity	
36 dBm ≤ 30 dBm	0.00%
< 30 dBm ≤ 24 dBm	0.00%
< 24 dBm ≤ 20 dBm	11.19%
< 20 dBm ≤ 17 dBm	4.16%
< 17 dBm ≤ 11 dBm	16.90%
< 11 dBm ≤ 0 dBm	58.73%
< 0 dBm	8.31%
Total	**100.00%**

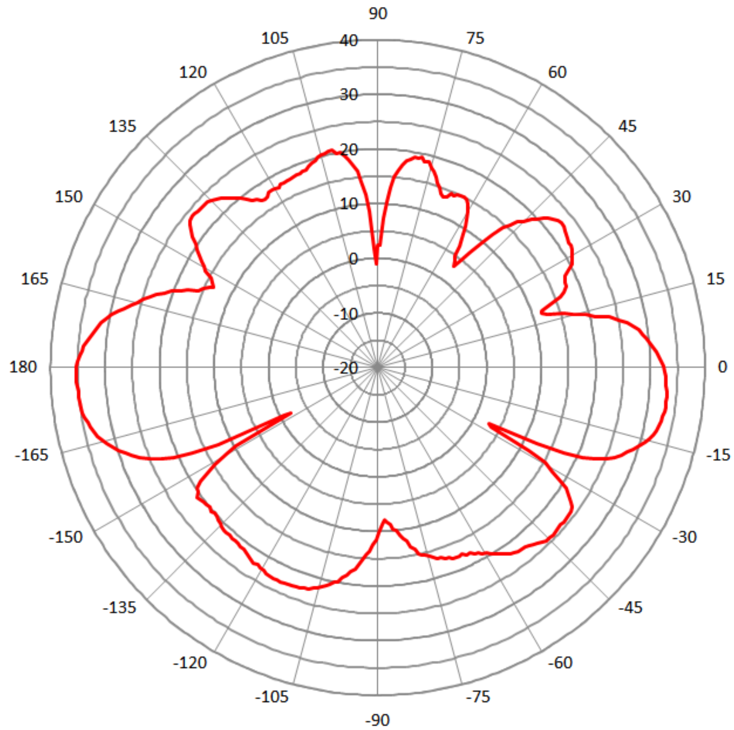


Figure 3-4 - Indoor High-Performance Gaming Router, Typical Pattern (EIRP)

Indoor High-Performance Gaming Router Access Point

EIRP Probability based on E-Plane Directivity

36 dBm ≤ 30 dBm	14.13%
< 30 dBm ≤ 24 dBm	8.86%
< 24 dBm ≤ 20 dBm	30.19%
< 20 dBm ≤ 17 dBm	21.33%
< 17 dBm ≤ 11 dBm	17.45%
< 11 dBm ≤ 0 dBm	7.20%
< 0 dBm	0.83%
Total	**100.00%**

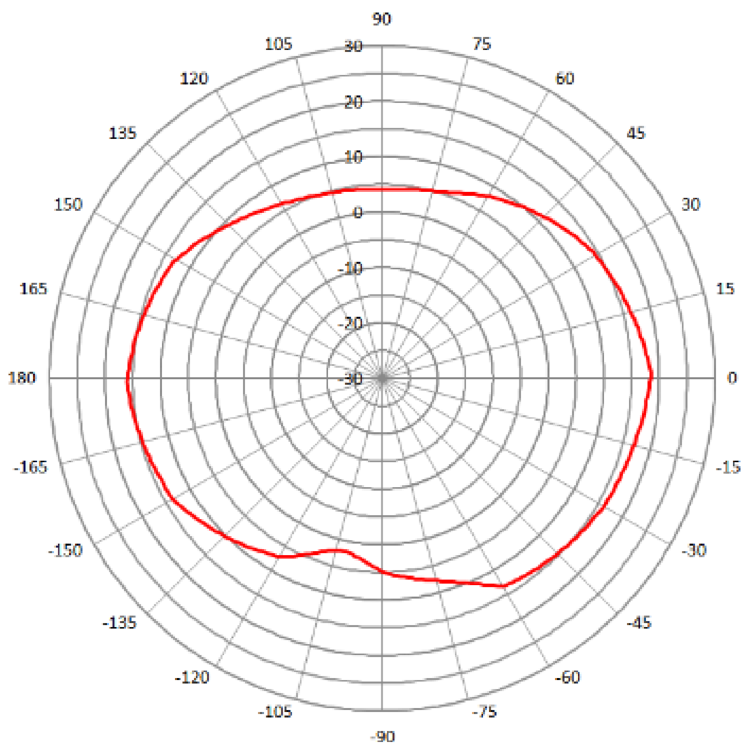


Figure 3-5 - Indoor and Outdoor Client, Typical Pattern (EIRP)

Indoor and Outdoor Client

EIRP Probability based on E-Plane Directivity

36 dBm ≤ 30 dBm	0.00%
< 30 dBm ≤ 24 dBm	0.00%
< 24 dBm ≤ 20 dBm	0.00%
< 20 dBm ≤ 17 dBm	6.93%
< 17 dBm ≤ 11 dBm	45.71%
< 11 dBm ≤ 0 dBm	47.37%
< 0 dBm	0.00%
Total	**100.00%**

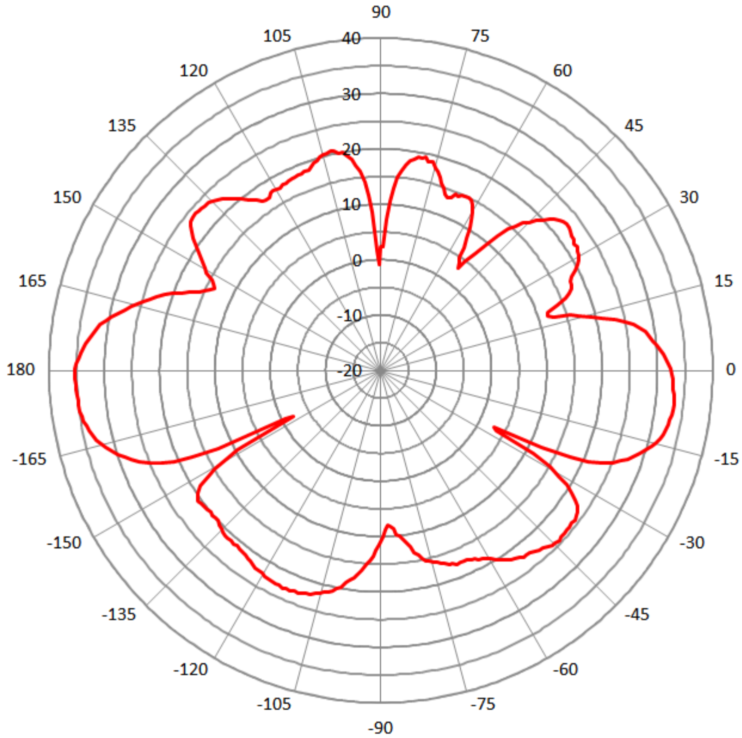


Figure 3-6 - Outdoor High-Power Access Point, Typical Pattern (EIRP)

Outdoor High-Power Access Point EIRP Probability based on E-Plane Directivity

36 dBm ≤ 30 dBm	14.13%
< 30 dBm ≤ 24 dBm	8.86%
< 24 dBm ≤ 20 dBm	30.19%
< 20 dBm ≤ 17 dBm	21.05%
< 17 dBm ≤ 11 dBm	17.73%
< 11 dBm ≤ 0 dBm	7.20%
< 0 dBm	0.83%
Total	**100.00%**

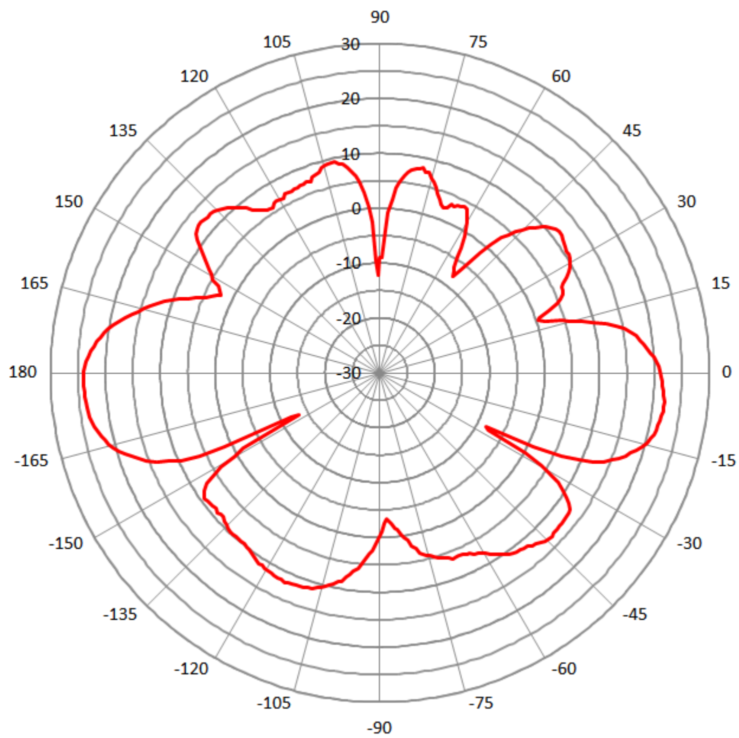


Figure 3-7 - Outdoor Low-Power Access Point, Typical Pattern (EIRP)

Outdoor Low Power Access Point EIRP Probability based on E-Plane Directivity

36 dBm ≤ 30 dBm	0.00%
< 30 dBm ≤ 24 dBm	0.83%
< 24 dBm ≤ 20 dBm	11.36%
< 20 dBm ≤ 17 dBm	4.43%
< 17 dBm ≤ 11 dBm	19.11%
< 11 dBm ≤ 0 dBm	56.23%
< 0 dBm	8.03%
Total	**100.00%**

The mix of indoor and outdoor RLANs is conservatively estimated at 98% and 2%, respectively (Section 3.1.1). Table 3-5 provides busy hour weights for indoor use cases. Note that device weights correspond to a 1:1 ratio of downlink to uplink traffic for corporate and public users, and a 2.3:1 ratio for home users.

Table 3-5 - Busy Hour Weights Assigned to Use Cases, Indoor Environments (by submarket)

User Type	**URBAN**			**SUBURBAN**			**RURAL**			**BARREN**		
Client	50%	50%	25%	50%	50%	25%	50%	50%	25%	50%	50%	25%
Enterprise AP	50%	50%	0%	50%	50%	0%	50%	50%	0%	50%	50%	0%
Consumer AP	0%	0%	70%	0%	0%	70%	0%	0%	70%	0%	0%	70%
High-Performance Gaming Router	0%	0%	5%	0%	0%	5%	0%	0%	5%	0%	0%	5%
Total (Indoor)	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Since outdoor RLAN usage is not expected to vary significantly by submarkets, all use cases were assigned the same weights in all submarkets (Table 3-6) and, for all outdoor scenarios, a 1:1 ratio of downlink to uplink traffic was used.

The combination of the use case busy hour weights of Tables 3-5 and 3-6, with the E-plane patterns shown in Figures 3-4 through 3-9, results in a power distribution for the source RLANs as shown in Table 3-7 for indoor RLANs and Table 3-8 for outdoor RLANs. This results in weighted average EIRPs for indoor RLANs of 19.167 dBm, outdoor RLANs of 22.73 dBm, and combined indoor/outdoor of 19.28 dBm are used in the simulations. It is noted that although these weighted average EIRP values were independently derived by the methods described above, the resulting values are consistent and slightly conservative compared to EIRP values used for previous RLAN sharing studies.[21,22,23]

Table 3-6 - Busy Hour Weights Assigned to Use Cases, Outdoor Environment (all sub-markets)

	URBAN	**SUBURBAN**	**RURAL**
Outdoor High-Power AP (Figure 3-8)	20%	20%	20%
Outdoor Low Power AP (Figure 3-9)	30%	30%	30%
Outdoor Client (Figure 3-7)	50%	50%	50%
Total (Indoor)	**100%**	**100%**	**100%**

The distributions in Tables 3-7 and 3-8 represent the probability of the specified EIRP occurring in any random direction from an active RLAN. For the purposes of simulation, the continuous values in between each breakpoint shown in the tables are represented as the maximum value. For example, the probability of a 250 mW EIRP from Table 3-7 for indoor RLANs of 10.39% is inclusive of all continuous EIRP probabilities greater than 100 mW, up to and including 250 mW, and were then

[21] ITU document Revision 1 to 5A/TEMP/236, Sharing and compatibility studies of WAS/RLAN in the 5 150-5 250 MHz frequency range, Section 5.1.1.4.2.1, average EIRP is 18.9 dBm for indoor RLANs, 21.2 dBm for outdoor RLANs, and 19 dBm for indoor and outdoor.
[22] ITU document Revision 1 to 5A/TEMP/236, Sharing and compatibility studies of WAS/RLAN in the 5 150-5 250 MHz frequency range, Appendix 2, Section 5.1.4.2.1, states average power used in the analysis was 19 dB with average.
[23] The ITU-R concludes that a mean EIRP of 19 dBm should be used for 5 GHz RLAN studies. ITU-R 5A/650 (Annex 22)-E at 3.

included in the simulation as 250 mW sources with a 10.39% probability of occurrence. Because the distributions of Tables 3-7 and 3-8 already assume the RLAN antenna orientation to the victim receive locations are random, no further adjustment is provided in the analysis for directivity effects of the RLAN sources. This is equivalent to stating that the above EIRP values are treated isotropically (radiate equally in all directions) once seeded into the model for a given source location. EIRP values above 1W up to and including 4W are modeled as isotropic for indoor use cases, but limited (truncated) to 1W at elevation angles above 30° for outdoor RLANs as described above.

Table 3-7 - LPI and Standard Power with AFC Indoor Source EIRP Distribution (mW)

		Weighted EIRP Distribution (mW)							
Indoor Use Case	**Weight**	**4000**	**1000**	**250**	**100**	**50**	**13**	**1**	**Total**
Client	26.32%	0.00%	0.00%	0.00%	1.82%	12.03%	12.47%	0.00%	26.32%
Enterprise AP	2.63%	0.00%	0.00%	1.06%	0.90%	0.58%	0.09%	0.01%	2.63%
Consumer AP	66.31%	0.00%	0.00%	7.90%	2.76%	11.20%	38.94%	5.51%	66.31%
High-Performance Gaming Router	4.74%	0.67%	0.42%	1.43%	1.01%	0.83%	0.34%	0.04%	4.74%
Sub-Total	**100.00%**	**0.67%**	**0.42%**	**10.39%**	**6.49%**	**24.64%**	**51.84%**	**5.56%**	**100.00%**

The weights shown in Table 3-7, that applies to LPI and Standard-Power Indoor devices, were obtained by combining the use cases of Table 3-5 with the active device populations shown in Table 3-1. For example, the indoor client weight of 26.32% is obtained as the weighted sum of the active devices inclusive of all submarkets as derived in the equation below.

Indoor Client Weight = {Table 3-5 [Urban (Corporate, Public, Home)] x Table 3-1 Device Population [Urban (Corporate, Public, Home)] + Table 3-5 [Suburban (Corporate, Public, Home)] x Table 3-1 Device Population [Suburban (Corporate, Public, Home)] + Table 3-5 [Rural (Corporate, Public, Home)] x Table 3-1 Device Population [Rural (Corporate, Public, Home)]} / {Table 3-1 [Total Active Devices]} *(3-6)*

The weights shown in Table 3-8, that applies to Outdoor Standard-Power devices, are the same as Table 3-6 for all outdoor devices because there is no variation assumed in the proportion of active devices for each use case across the sub-markets.

Table 3-8 – Outdoor Standard Power with AFC RLAN Source EIRP Distribution (mW)

		Weighted EIRP Distribution (mW)							
Outdoor Use Case	**Weight**	**4000**	**1000**	**250**	**100**	**50**	**13**	**1**	**Total**
High Power AP	20%	2.83%	1.77%	6.04%	4.21%	3.55%	1.44%	0.17%	20.00%
Low Power AP	30%	0.00%	0.25%	3.41%	1.33%	5.73%	16.87%	2.41%	30.00%
Client	50%	0.00%	0.00%	0.00%	3.46%	22.85%	23.68%	0.00%	50.00%
Sub-Total	**100.00%**	**2.83%**	**2.02%**	**9.45%**	**9.00%**	**32.13%**	**41.99%**	**2.58%**	**100%**

For the simulation, interference results are presented as the aggregate interference from a deployment of all RLAN device types.

3.2.2 Body Loss for LPI and Standard Power with AFC Indoor and Outdoor devices

RF signal attenuation that is caused by the human body is typically taken into account in sharing studies with mobile client devices. A fixed body loss value of 4 dB is applied when the modelled LPI or Standard Power with AFC RLAN device is a client, while body loss is assumed to be non-existent for Access Point devices. The percentage of client devices is given as 26.32% and 50% for indoor and outdoor deployments, respectively, in Section 3.2.1. Hence, the following methodology is applied in the Monte-Carlo simulations for LPI and indoor and outdoor Standard Power with AFC devices:

a) For indoor devices, apply 4 dB additional loss for 26.32% of the devices (cliets)

b) For outdoor devices, apply 4 dB additional loss for 50% of the devices (clients)

3.2.3 Distribution of Source VLP Power Levels including Body Loss

For VLP devices where the body interacts with the device (because the device is closer to body), for higher accuracy, the full distribution of body loss is used. Antenna gain measurements were made in proximity of the human body considering various use case device positioning, static vs. dynamic conditions, device orientations, and the physical characteristics of the human body. The comprehensive on-body over-the-air measurements and analysis of the associated body loss distributions applicable to the indoor and outdoor VLP device are described in the Wireless Research Center of North Carolina study attached to the RLAN Group Comments, and shown in Figure 3-8.[24] In the Monte-Carlo simulations, antenna gain values ($G_{FarField}$ in Eqn. 2-1) are selected randomly from the distribution in Figure 3-8 and is added to a fixed value of 14 dBm to get the net EIRP level that includes antenna mismatch and body loss for indoor and outdoor VLP devices.

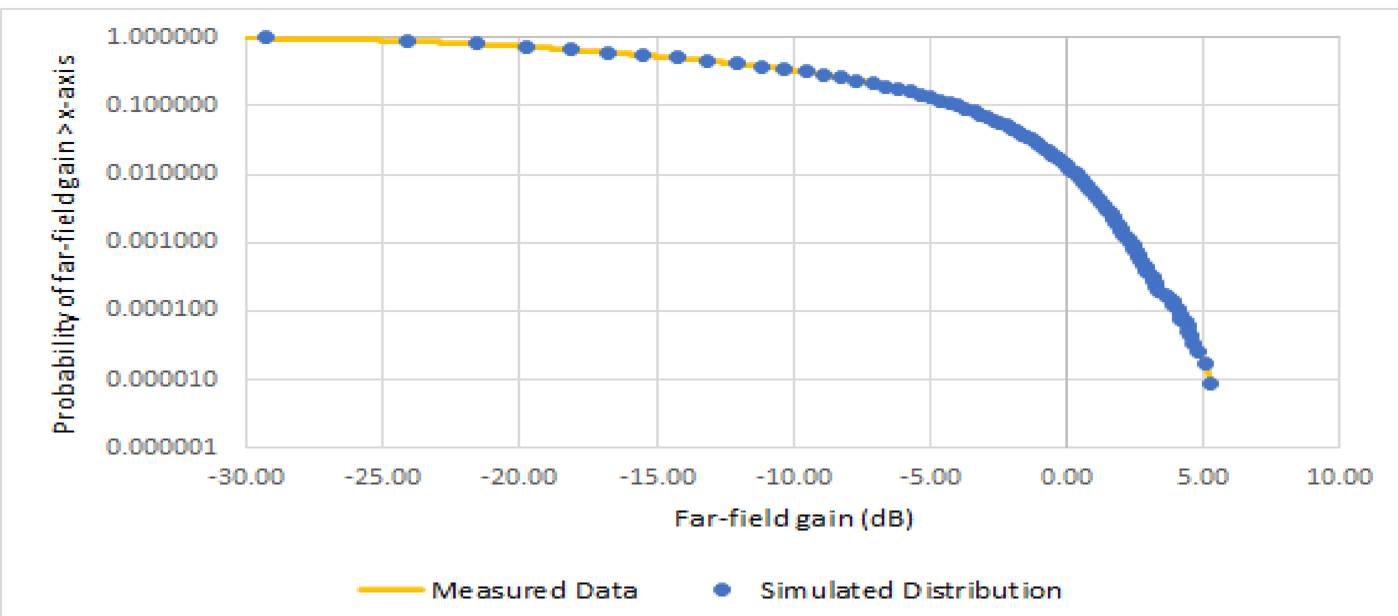


Figure 3-8 – Probability of VLP device far-field gain > x-axis: measurements versus simulated distribution

[24] Wireless Research Center of North Carolina, On-Body Channel Model and Interference Estimation at 5.9 GHz to 7.1 GHz Band at Fig. 26 (June 2020).

3.2.4 Bandwidth and Channel Distribution

RLANs modeled in this report are assumed to operate in 20 MHz, 40 MHz, 80 MHz, and 160 MHz bandwidth channels. To determine the number of channels, and how those channels may overlap with FSS and FS receivers, the following channel plan outlined in Figure 3-9 was assumed. Note that the 20-MHz channel from 5925-5945 MHz (channel index 2) was not included in the model.

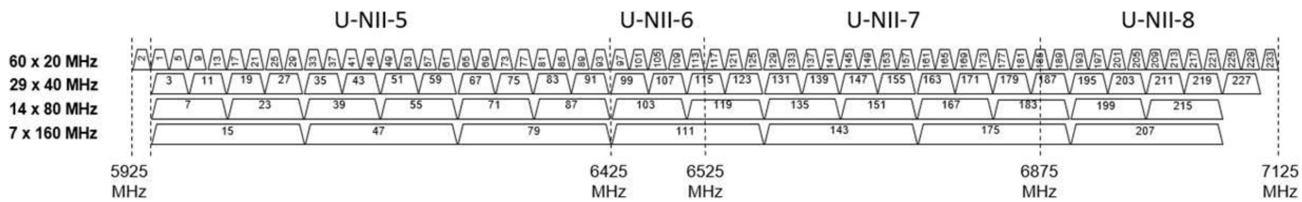


Figure 3-9 -Assumed RLAN Channel Plan

The bandwidth distribution in Table 3-9 is based on the assumption that RLAN systems will operate with larger channel sizes to maximize airtime efficiency, resulting in lower latency, higher throughput, and improved battery life.

Table 3-9 – RLAN Channel Distribution

Bandwidth	**20 MHz**	**40 MHz**	**80 MHz**	**160 MHz**
Percentage	10%	10%	50%	30%

3.2.3 Distribution of RLAN heights

Outdoor VLP devices are worn on mobile users, and a large majority of these use cases are with the VLP device below 1.5 m.

To assign an RLAN transmit source height to the remaining RLAN classes (i.e., LPI, indoor VLPs and indoor/outdoor Standard Power with AFC devices (here-in after referred to "RLANs" in this section), a height distribution was separately prepared for each of the following indoor environments: urban, suburban, and rural. In addition, a common outdoor height distribution was used for all environments. The starting point of the height distribution is the building construction type probability for each environment, shown in Table 3-10. [25]

Within multi-story buildings, the distribution of RLANs is assumed to have an equal probability of occurring on any floor up to ten stories. A height of ten stories was selected as the maximum because the probability of RLANs on higher floors diminishes significantly even when taller buildings are considered. Stated differently, studying taller buildings does not impact the analysis in any significant way. This is due to the assumed equal spreading of RLANs on all floors of a tall building, which results in the combined distribution being heavily weighted toward lower floors.

[25] U.S. Energy Info. Admin., *2012 Commercial Buildings Energy Consumption Survey: Building Questionnaire - Form EIA-871A*, https://www.eia.gov/consumption/commercial/data/2012/pdf/questionnaire.pdf; NAHB, *The Number of Stores in Single-Family Homes Varies Across the Country*, Aug. 5, 2016, http://eyeonhousing.org/2016/08/the-number-of-stories-in-single-family-homes-varies-across-the-country/.

For example, the 28.5m height assumed for RLANs on the 10th floor of a ten-story building comprises only 0.02% of all RLANs in the Urban environment. It is noted that the inclusion of the 10-story building in the analysis, while placing 0.02% of RLANs at this height, increases

Table 3-10 - Building Construction Type Probability by Environment

		Urban Indoor			**Suburban Indoor**			**Rural Indoor**			**Outdoor**
Building Story	Height (m)	Corp	Public	Home	Corp*	Public	Home	Corp	Public	Home	
1	1.5	69.0%	69.0%	60.0%	69.0%	69.0%	60.0%	70%	70%	70%	95%
2	4.5	21.0%	21.0%	30.0%	21.0%	21.0%	30.0%	25%	25%	25%	2%
3	7.5	7.0%	7.0%	7.0%	7.0%	7.0%	5%	5%	5%	5%	2%
4	10.5	0.7%	0.7%	0.7%	0.7%	0.7%	5%	0%	0%	0%	0.5%
5	13.5	0.58%	0.6%	0.6%	0.58%	0.6%	0%	0%	0%	0%	0%
6	16.5	0.50%	0.5%	0.5%	0.50%	0.5%	0%	0%	0%	0%	0%
7	19.5	0.43%	0.4%	0.4%	0.43%	0.4%	0%	0%	0%	0%	0%
8	22.5	0.35%	0.4%	0.4%	0.35%	0.4%	0%	0%	0%	0%	0%
9	25.5	0.28%	0.3%	0.3%	0.28%	0.3%	0%	0%	0%	0%	0%
10	28.5	0.2%	0.2%	0.2%	0.2%	0.2%	0%	0%	0%	0%	0.5%
Total		**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

the probability of RLANs at heights on floors one through nine by 10% of the ten-story building type probability. For example, the likelihood that an RLAN will be on the first floor in an urban environment is the sum as follows:

RLAN on 1st Floor Probability = 1 Story Building Probability + 2 Story Building Probability/2 Floors … +10 Story Building Probability/10 Floors (3-7)

As such, including buildings of taller heights provides limited additional insight into the question of aggregated RLAN interference because each additional building height of *n* stories that is included provides only a 1/*n* contribution to the distribution of RLANs at that height, while the rest are distributed as 1/*n* to each of the lower floors.

Using the above described method based on the building construction type probability and equal assignment of RLANs to each floor of a multi-story building results in the distribution of source heights shown in Table 3-11.

Table 3-11 - RLAN Source Height Distributions

		Urban Indoor			**Suburban Indoor**			**Rural Indoor**			**Outdoor**
Building Story	Height (m)	Corp	Public	Home	Corp*	Public	Home	Corp	Public	Home	
1	1.5	82.35 %	82.35 %	77.85 %	82.35 %	82.35 %	77.92 %	84.17 %	84.17 %	84.17 %	95.00%
2	4.5	13.35 %	13.35 %	17.85 %	13.35 %	13.35 %	17.92 %	14.17 %	14.17 %	14.17 %	2.00%
3	7.5	2.85%	2.85%	2.85%	2.85%	2.85%	2.92%	1.67%	1.67%	1.67%	2.00%
4	10.5	0.52%	0.52%	0.52%	0.52%	0.52%	1.25%	0.00%	0.00%	0.00%	0.50%
5	13.5	0.36%	0.36%	0.36%	0.36%	0.36%	0.00%	0.00%	0.00%	0.00%	0.00%

6	16.5	0.24%	0.24%	0.24%	0.24%	0.24%	0.00%	0.00%	0.00%	0.00%	0.00%
7	19.5	0.16%	0.16%	0.16%	0.16%	0.16%	0.00%	0.00%	0.00%	0.00%	0.00%
8	22.5	0.09%	0.09%	0.09%	0.09%	0.09%	0.00%	0.00%	0.00%	0.00%	0.00%
9	25.5	0.05%	0.05%	0.05%	0.05%	0.05%	0.00%	0.00%	0.00%	0.00%	0.00%
10	28.5	0.02%	0.02%	0.02%	0.02%	0.02%	0.00%	0.00%	0.00%	0.00%	0.50%
Total		**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

4 Propagation Models

The interference paths from a large deployment of RLANs to other services will vary considerably with terrain, local ground clutter, and the location of the RLAN installation (e.g., indoor or outdoor, building heights, building type, density of buildings, etc.). Interference estimates therefore require statistical propagation models that can account for this large variability and random nature of some of the propagation effects.

Section 4.1 describes propagation models used by RKF to calculate path loss for RLAN interference to the FSS. Section 4.2 describes propagation models used to calculate path loss for RLAN interference to terrestrial services. Section 4.3 describes the propagation models used to calculate the path losss for the RLAN interference into the earth station antenna at the MSS gateway.

4.1 RLAN to FSS Propagation Models (Earth to Space)

Figure 4-1 shows possible interference paths from terrestrial sources to satellites on the geosynchronous (GEO) arc. Paths from indoor devices will experience penetration losses through buildings. Some paths will then interact with terrain, while others will suffer from local end-point clutter (e.g., buildings), and still others will have line-of-site (LOS) visibility to the GEO arc.

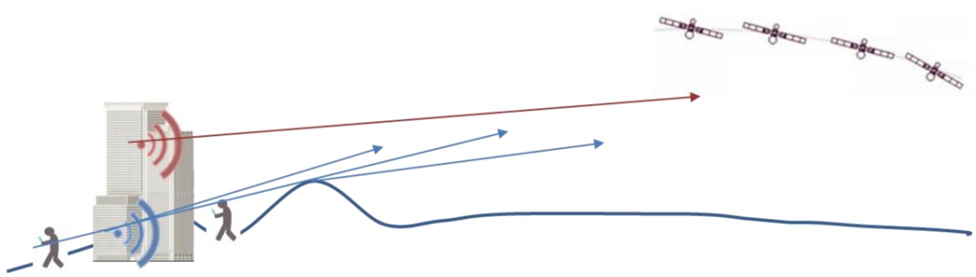


Figure 4-1 - Typical Interference Paths toward the GEO Arc

Figure 4-1 Key	
	Indoor RLAN
	Outdoor RLAN
	LOS Path
	Paths that interact with terrain and/or suffer from end-point-clutter

Paths from indoor RLANs to terrestrial systems experience penetration loss calculated using Recommendation ITU-R P.2109 (P.2109) as the path exits a building. P.2109 is a heuristic model based on many measurements with users located randomly within a building. It considers the elevation angle of the signal leaving the building to the affected receiver. Two types of buildings are defined:

traditional and thermally efficient. Penetration losses through thermally efficient buildings are higher than traditional buildings. The models conservatively assume 80% of buildings are traditional and 20% of buildings are thermally efficient.[26]

Local end-point clutter is added using Recommendation ITU-R P.2108 (P.2108), Section 3.3 (for Earth-space paths). This is a statistical clutter model for urban and suburban areas. It accounts for the elevation angles from the transmitters to the satellites. According to guidance from ITU-R Study Group 3, the model is currently used only for frequencies above 10 GHz.[27] This is because building penetration is not taken into account. However, it is reasonable to assume that at 6 GHz, buildings will be mostly opaque (i.e., large losses will occur transmitting through buildings). This is verified using P.2109 for indoor users, where average penetration loss through traditional buildings at 6 GHz and at an elevation angle of 30° is about 20 dB.

To estimate rural clutter loss, Recommendation ITU-R P.452 (P.452) was used with RLANs deployed predominately in village centers. P.452 assumes that in village centers clutter height is 5 m and the distance to the clutter is 0.07 km which equals an angle of 2.86^{o}. Therefore, in the simulations, when the rural RLAN height is 1.5 m, a clutter loss of 18.4 dB was added when the look angle to the FSS receiver was $\leq 2.86^{o}$. When rural RLAN heights are above 1.5m, the clutter loss is assumed to be negligible and is not calculated.

For LOS paths, the radio horizon is defined using 4/3 earth assumptions. Free space path loss is used when there is no blockage from the transmitter to the satellite. Conservatively, atmospheric loss, which is small, was ignored in this calculation.

4.2 RLAN to Terrestrial FS Propagation Models

Possible interference paths from RLANs to terrestrial FS systems are similar to those described in Section 4.1 for paths from terrestrial systems to satellites on the GEO arc, with the addition of a terrain model (as described below). Like Section 4.1, paths from indoor RLANs to terrestrial systems experience penetration loss calculated using P.2109 as the path exits a building.

The Irregular Terrain Model (ITM) model of radio propagation is a general-purpose model for frequencies between 20 MHz and 20 GHz that can be applied to a large variety of engineering problems. The model, which is based on electromagnetic theory and statistical analyses of both terrain features and radio measurements, predicts the median attenuation of a radio signal as a function of distance and the variability of the signal in time and in space. The ITM, along with the Shuttle Radar Topography Model (SRTM) (3 sec) terrain database, is used to model terrain interactions. The ITM uses the SRTM terrain elevation data along with diffraction theory to calculate the path loss when there is terrain blockage.

The analyses use propagation models adopted per the FCC's 6 GHz Report & Order.[28] As a function of the separation distance between the RLAN and victim receiver, these models are as follows:

[26] *Note that in the US, the 6 GHz Report and Order used 70% traditional and 30% thermally-efficient.*
[27] 5A/337-E, 3 April 2017, Working Parties 3K and 3M, LIAISON STATEMENT TO WORKING PARTY 5A, PROPAGATION MODELS FOR COMPATIBILITY STUDIES REGARDING WRC-19 AGENDA ITEM 1.16.
[28] *6 GHz Report and Order*.

- "[F]or separation distances of 30 meters or less, the free space pathloss model is the appropriate model."[29]

- "Beyond 30 meters and up to one kilometer from an unlicensed device to a microwave receiver, we find that the most appropriate propagation model is the Wireless World Initiative New Radio phase II (WINNER II)."[30]

- "For separation distances greater than one kilometer . . . the Irregular Terrain Model combined with a clutter model depending on the environment is the most appropriate model."[31]

These models are summarized in Table 4-1 below:

Table 4-1 - Summary of Propagation Model

Distance (Slant Range) from RLAN to Victim Receiver	**Propagation Model**
Up to 30 meters	Free Space Path Loss (FSPL)
30 meters to 1 km	*Combined LOS/NLOS Winner II* ● Urban VLP: Winner II Scenario C2 ● Suburban VLP: Winner II Scenario C1 ● Rural VLP: Winner II Scenario D1
Above 1 km	*ITM + Clutter model* Clutter model ● Urban/Suburban VLP: ITU-R Rec. P.2108-0 (Section 3.2.2) ● Rural VLP: ITU-R Rec. P.452 Village Center Clutter

The combined median path loss model is computed using Eqn. 4-1 for distances between 30 m and 1 Km.

$$PL_{CWII}\ (dB) = PL_{LOS}\ (dB) \times Prob_{LOS} + PL_{NLOS}\ (dB) \times \{1-Prob_{LOS}\} \qquad (4\text{-}1)$$

where,

- PL_{LOS} and PL_{NLOS} are the Line-of-Sight (LOS) and NLOS Path Losses per Table 4-4 in WINNER II Report[32]

- $Prob_{LOS}$ is the LOS Probability per Table 4-7 in WINNER II Report

[29] *Id.* ¶ 64.
[30] *See id.* ¶ 66 (referencing the urban, suburban, and rural WINNER II channel models as C2, C1, and D1, respectively). *See also* WINNER & Information Society Technologies, *WINNER II Channel Models Part 1*, Table 2-1 Propagation scenarios specified in WINNER and Table 4-4 Summary table of the path-loss models, https://www.cept.org/files/8339/winner2%20-%20final%20report.pdf ("WINNER II Channel Models").
[31] *See 6 GHz Report and Order* ¶ 68 (referencing the *Irregular Terrain Model Guide*). *See also* G.A. Hufford et al., *A Guide to the Use of the ITS Irregular Terrain Model in the Area Prediction Mode*, NTIA Report 82-100 (1982), https://www.ntia.doc.gov/files/ntia/publications/ntia_82-100_20121129145031_555510.pdf.
[32] *See* WINNER II Channel Models.

In addition to the combined median path loss term, the Winner II LOS and NLOS Path Loss components include a random lognormal shadowing term that is included in the simulations.

For distances above 1 km, ITM with the SRTM 3-arc-seconds Terrain Database is used. The P.452 village center clutter loss of 18.4 dB is used for the 1.5m RLAN device when the following conditions are met:

- RLAN elevation angle towards the victim receiver ≤ 2.86 deg (corresponding to a VLP deployed at an average distance from a village building of average height), AND

  RLAN distance to victim receiver ≥ 0.7 km

4.3 RLAN to Terrestrial MSS Gateway Models

Possible interference paths from RLANs to the earth stations antenna at the future MSS gateway site are similar to those described in Section 4.2 for paths from terrestrial systems to terrestrial FS systems, which includes a terrain model. Like Sections 4.1 and 4.2, paths from indoor RLANs to MSS gateway antenna experience penetration loss calculated using P.2109 as the path exits a building.

The MSS downlink signal from the selected MSS satellite at the randomly selected moment in time received at the MSS gateway's earth station is line-of-site and thus the free space path loss model was used.

5 Sharing Results

5.1 FSS Uplink Sharing

This section reports the results of an aggregate I/N calculation into a number of satellite uplink beams using the RLAN deployment per Section 3.1.1 and available satellite G/T contours[33], related to the satellites in Table 5-1. A search of the ITU BR IFIC database provided information on the 52 satellites that Mexico brought to use in the 6 GHz band. For purposes of providing a conservative analysis, satellite beams with higher G/T over Mexico or bigger coverage of areas have been chosen. Peak G/T levels per the satellites' filings are used to derive the absolute G/T levels from the G/T contours (that indicate amount of dB down from peak G/T). In addition to the three Satelites Mexicanos, S.A. DE C.V. satellites (Satmex 6, Satemex, and Satmex 8), three other satellites were selected based on their maximum G/T value over Mexico. Consequently, no effort was made to establish whether any of the three latter satellites selected are currently in use over Mexico. For example, the satellite could have provided coverage over Mexico when launched, but it may have been relocated subsequently to provide coverage to a different geography. In another instance, the satellite could have been in operation for years, but no longer. If the risk of harmful interference from 6 GHz RLAN operations to the satellite-based fixed service uplinks for each of these six satellites is negligible, then the presumption is that risk of harmful interference to other satellites providing service across Mexico is even less.

[33] Extracted from ITU BR IFIC

The analysis has been applied to a satellite channel plan assuming 36 MHz channels in 40 MHz occupied bandwidth on two polarizations. Each channel on each satellite has been subject to 10 independent RLAN deployments of a Monte Carlo simulation as detailed in the next Section.
Table 5-1 gives the worst I/N value found for each beam across all channels. The table shows that, in all cases, the I/N is lower than absolute value of -26.92 dB.

Table 5-1 - Summary worst-case I/N into FSS

Satellite Longitude	Satellite Name	Beam Reference	Populations included in calculation	Worst aggregate I/N (dB)
116.8° West	Satmex 8	cuh.gxt	Mexico, all of the Americas and the Caribbean	-30.15
114.9° West	Eutelsat 115 West B (Satmex 7)	crhco.gxt	Mexico, all of the Americas and the Caribbean	-27.08
113° West	Satmex 6	chuh.gxt	Mexico, all of the Americas and the Caribbean	-31.01
103° West	SES-3	crv.gxt	Mexico, all of the Americas and the Caribbean	-31.34
97° West	Galaxy 19	crf_c.gxt	Mexico, all of the Americas and the Caribbean	-29.73
47.5° West	NSS-806	hau.gxt	Mexico, all of the Americas and the Caribbean, Europe, Africa	-26.92

5.1.1 FSS Simulation Methodology

Interference from RLAN deployments into FSS satellite receiver is simulated using a Monte Carlo simulation of the RLAN deployment generated from the various probability distributions given in Section 3.
The basic structure of the simulation is as follows:

1. Data setup:
    a. Define the simulation region and create a database of population density at points within the simulation region;
    b. Transform population data over the simulation region to active RLAN device population probability distribution over the simulation region;
    c. Specify the orbital slot of the FSS satellite receiver and the G/T values over the simulation region;
    d. Specify a list of FSS satellite channels to simulate.

2. Monte-Carlo iterations:

a. Generate a random layout of RLANs using the device population probability distribution;

b. Generate a random transmit EIRP, height, body loss, RLAN channel, clutter loss and building entry loss values between each RLAN and FSS satellite receiver in accordance with the RLAN distributions in Section 3.2 and propagation modelling set out in Section 4;

c. Compute the aggregate interference from all co-channel RLANs into the FSS satellite receiver for each of the simulated FSS channels.

3. Iterate:
   a. Repeat Step 2 for the total specified number of iterations;

   b. Record I/N values for each FSS channel on each iteration and write results to a file.

4. Average the recorded aggregate I/N values (over the performed iterations) to create plot of average I/N versus FSS channel number.

Steps 1 and 2 above are further elaborated below.

Step 1: Data Setup

A population matrix file is created. Each row/line of the matrix contains a Longitude (LON)/Latitude (LAT) coordinate and the population density at that location. Furthermore, there is a region ID that specifies if the point is in Europe, Africa, Mexico or the Americas but not in Mexico. The matrix resolution is 30 arcseconds for both LON and LAT coordinates.
Note that the collection of all points in the population density file defines the simulation region and the simulation region is, in general, not rectangular. Grid points that are in the ocean or other locations that are not part of the simulation are omitted from the population density file. Each grid point is classified as being URBAN, SUBURBAN or RURAL depending on the population density value for the grid point and threshold values that are inputs to the simulation.

The population density file is used to produce the active RLAN device population probability distribution over the simulation region. The first step is to convert population density values into population values for each grid point by multiplying the population density by the area of the 30 arcsec x 30 arcsec region centered at the grid point. These population values are then summed for each of the regions Europe, Africa, Mexico and Americas[34] but not in Mexico.

Let PE, PA, PM and PN be the populations of Europe, Africa, Mexico and the Americas but not in Mexico respectively. Let NE, NA, NM, NN be the number of active RLAN devices in each region respectively. These values are inputs to the simulation.

For each grid point, the population value is converted to the average active RLAN device count by multiplying by (NE/PE), (NA/PA), (NM/PM) or (NN/PN) depending on whether the grid point is in Europe, Africa, Mexico, or the Americas but not in Mexico. This is then converted into a large discrete probability distribution function where each grid point is assigned a probability equal to the average RLAN device count at that grid point divided by the total active RLAN device count. A random RLAN position is generated by generating a random grid point using this discrete probability distribution, then

[34] Americas refers to Central America, North America, South America and the Caribbean.

selecting a location uniformly distributed over the 30 arcsec x 30 arcsec region centered at the grid point.

The values of G/T over the simulation region are specified in the GXT format. This standard file format specifies contours over which G/T values are constant. Given an arbitrary LON/LAT position, two contours are identified for which this position is between and the G/T value is taken to be the average of the corresponding G/T values. Furthermore, the region outside the outermost contour, when less than or equal to 20 dB below the peak, is set to that contour. When the outermost contour is greater than 20 dB below peak (e.g., 10 dB below peak), the region is set 20 dB below peak in the absence of the beam roll-off pattern.

The list of FSS channels to be simulated is specified by a channel bandwidth, center-to-center channel spacing, start center frequency and number of channels simulated. Figure 5-1 shows the nominal FSS transponder plan between 5925 to 6425 MHz that has been assumed. Each transponder has a bandwidth of 36 MHz and is spaced 40 MHz apart. Over this 500 MHz band there are 24 transponders, 12 in each polarization. The channel center frequencies for each polarization are staggered by 20 MHz. The start frequency is 5927 MHz.

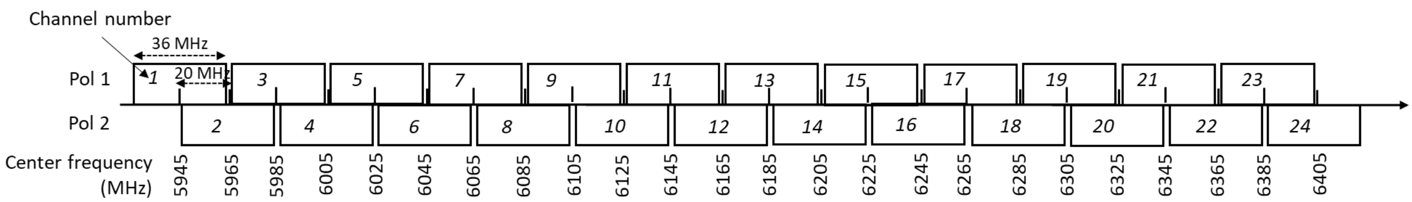


Figure 5-1 - Representative FSS Transponder Frequency Plan (fc, Separation=40MHz per polarization (Pol))

Step 2: Monte Carlo Iterations

For each iteration, a random layout of active RLAN devices is generated one RLAN at a time. Each RLAN device is assigned a random longitude/latitude position generated using the device population probability distribution described above. Each RLAN device is assigned a random height, EIRP, body loss, and building type using discrete probability distributions according to Section 3.2. Building types are outdoor (meaning no building attenuation) RLAN, indoor-traditional or thermally efficient (respecting a 20% thermally efficient/ 80% traditional balance). Each RLAN is assigned a random bandwidth using a discrete probability distribution as in Table 3-9 and a random center frequency as in Figure 3-9. The center frequency is generated by considering all possible center frequencies for the selected bandwidth and using a uniform distribution.

For each RLAN, a 4/3 earth model is used to determine whether the satellite is in view or over the horizon. RLANs for which the satellite is not in view are considered to contribute no interference to the satellite and are thus ignored in the interference calculation.

For each FSS channel in the simulation, interference from all RLANs for which the satellite is in view is computed and aggregated. The RLAN bandwidth and center frequency along with the FSS channel bandwidth and center frequency are used to compute the fraction of the WAS/RLAN bandwidth that overlaps with the FSS channel. If there is no overlap, the RLAN contributes no interference to the FSS channel. In addition, a random body loss is generated using discrete probability distributions described in Sections 3.2.2 and 3.2.3.

A random building entry loss is computed using Recommendation ITU-R P.2109-0 using the building type and elevation angle from the RLAN to the FSS satellite receiver orbital slot. Note that for outdoor RLANs the building entry loss is 0 dB. Random path clutter values are generated per Recommendation ITU-R P.2108 for urban and suburban RLANs and per Recommendation ITU-R P.452 for rural RLANs (as described in Section 4).

The path loss is computed using Free Space Path Loss (FSPL), per Recommendation ITU-R P.619-3, from the RLAN position to the FSS satellite orbital slot. Polarization loss of 3 dB is added. The FSS satellite Figure-of-Merit (G/T) is computed at the RLAN position as described above. The I/N contribution for a single RLAN into an FSS channel is computed by:

$$\frac{I}{N} = EIRP + G_{FarField} - L_{Body} - L_{Bldg} - FSPL - L_{Clutter} - L_{Polarization} - L_{SpectralOverlap} + \frac{G}{T} - 10log_{10}(kB)$$

Where,

- $EIRP$ (dBW) = RLAN EIRP (Table 3-4 as modified by Table 3-7 and Table 3-8) for LPI and Standard Power; 14 dBm for VLP) within RLAN channel bandwidth (Table 3-9)
- $G_{FarField}$ (dB) = VLP far field gain that includes body loss (see Section 3.2.3); 0 dB for LPI and Standard Power RLANs
- L_{Body} (dB) = LPI and Standard Power Body Loss (see Section **Error! Reference source not found.**); 0 dB for LPI
- L_{Bldg} (dB) = Building Entry Loss
- $FSPL$ (dB) = 92.45 + 20*log10(RLAN center frequency in GHz) + 20*log10(RLAN distance to FS Rx in Km)
- $L_{Clutter}$ (dB) = Clutter Loss
- $L_{Polarization}$ (dB) = Polarization Loss of 3 dB
- $L_{SpectralOverlap}$ (dB) = 10*log10(spectrum overlap between RLAN channel and victim channel / RLAN bandwidth), also called frequency-dependent rejection
- $\frac{G}{T}$ (dB/K) = Satellite receiver Figure-of-Merit (dB/K)
- k (J/K) = Boltzmann's constant = $1.3806488 \times 10^{-23}$
- B (Hz) = FSS channel bandwidth (Hz)

This I/N is aggregated over all RLANs for each FSS channel in the simulation.

5.1.2 RLAN Populations used in the Simulations

The following total population projections for 2025, for each region, have been used in generating RLAN deployments in the simulations.

1. Mexico, Total population: 141,132,000
2. The Americas (except Mexico) and the Caribbean, Total population: 934,760,659

3. Europe (48 CEPT states), Total Population: 768,589,000[35]
4. Africa, Total Population: 1,407,870,000[36]

Using the total populations per above and same[37] assumptions as Table 3-1, Table 5-2 shows number of simultaneously transmitting RLAN devices that are simulated in each region within the satellite footprint. In addition, the number of active RLANs in Africa is divided by factor of 4[38] to reflect the delay in maturity of RLANs deployment at 6 GHz.

Table 5-2 – Number of active RLAN devices simulated

Region	2025 Population	Number of instantaneously transmitting RLAN devices
Mexico	141,132,000	179,261
The Americas (except Mexico) and the Caribbean	934,760,659	1,194,849
Europe	768,589,000	988,040
Africa	1,407,870,000	458,132

5.1.3 Results by FSS Satellite Beam

5.1.3.1 Satmex 8 (116.8° W)

The Satmex-8 satellite at 116.8° west has a hemispheric beam with a peak G/T of 1.3 dB/K. The G/T contours are shown below.

[35] CEPT ECC, *Report 302: Sharing and Compatibility Studies Related to Wireless Access Systems Including Radio Local Area Networks (WAS/RLAN) in the Frequency Band 5925-6425 MHz* (May 29, 2019), https://docdb.cept.org/download/cc03c766-35f8/ECC%20Report%20302.pdf ("ECC Report 302"). Page 86.
[36] *Id.*
[37] Except for the percentage of population in Urban/Suburban/Rural that were derived for each region using the population density thresholds in Section 3.1.2.
[38] ECC Report 302, Page 87.

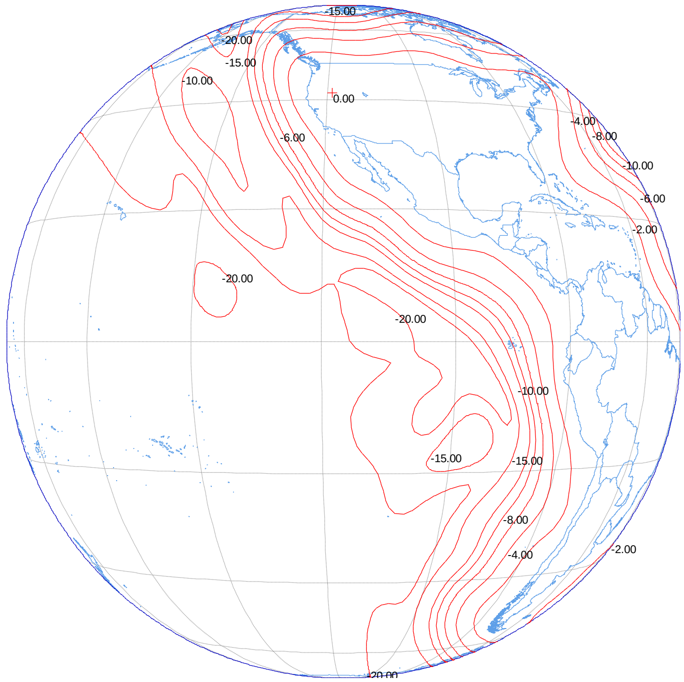


Figure 5-2: Satmex-8 G/T Contours (cuh.gxt)

The aggregate I/N across the 24 modelled FSS channels, averaged over 10 simulation iterations is shown in the figure below. The calculation includes RLANs in Mexico, Central America, North America, South America and the Caribbean.

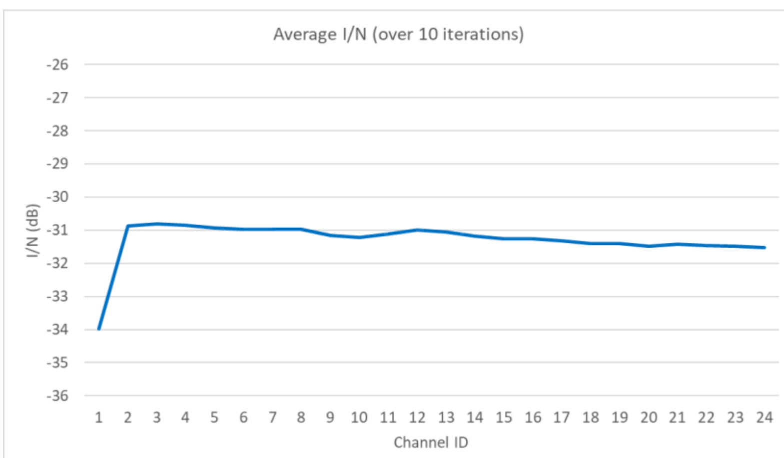


Figure 5-3: Satmex-8 I/N per channel

The maximum I/N found in a single iteration is -30.15 dB. The maximum averaged over 10 iterations is -30.82 dB.

5.1.3.2 Eutelsat 115 West-B (Satmex 7) (114.9° W)

The Eutelsat 115 West-B satellite at 114.9° west has a hemispheric beam with a peak G/T of 5.8 dB/K. The G/T contours are shown below.

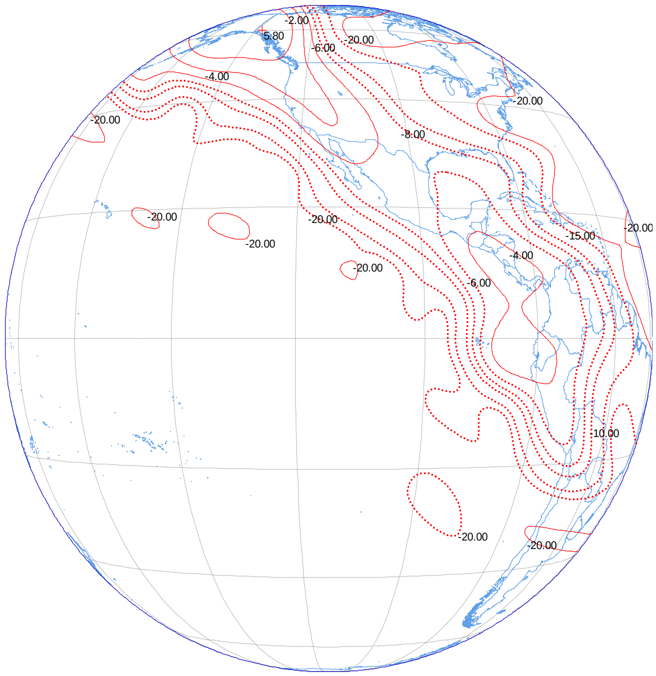


Figure 5-4: Eutelsat 115 West-B G/T Contours (crhco.gxt)

The aggregate I/N across the 24 modelled FSS channels, averaged over 10 simulation iterations is shown in the figure below. The calculation includes RLANs in Mexico, Central America, North America, South America and the Caribbean.

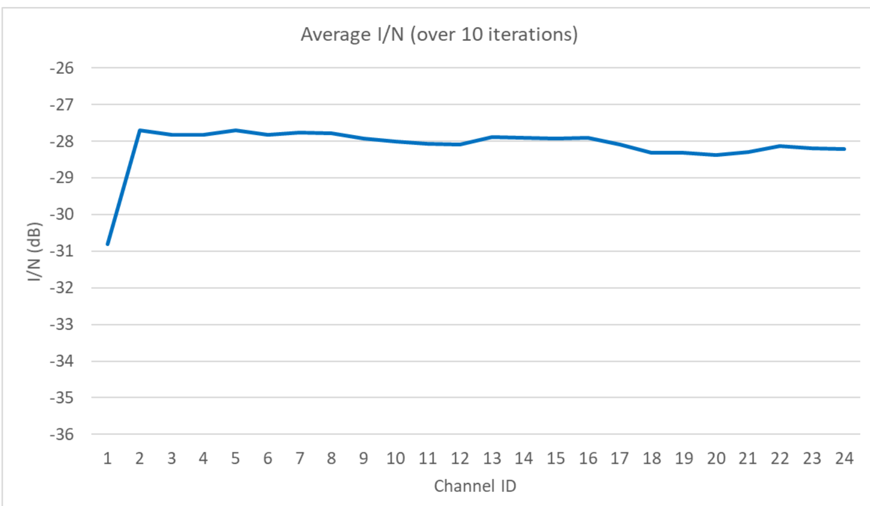


Figure 5-5: Eutelsat 115 West-B I/N per channel

The maximum I/N found in a single iteration is -27.08 dB. The maximum averaged over 10 iterations is -27.70 dB.

5.1.3.3 Satmex 6 (113° W)

The Satmex-6 satellite at 113° west has a hemispheric beam with a peak G/T of 1.7 dB/K. The G/T contours are shown below.

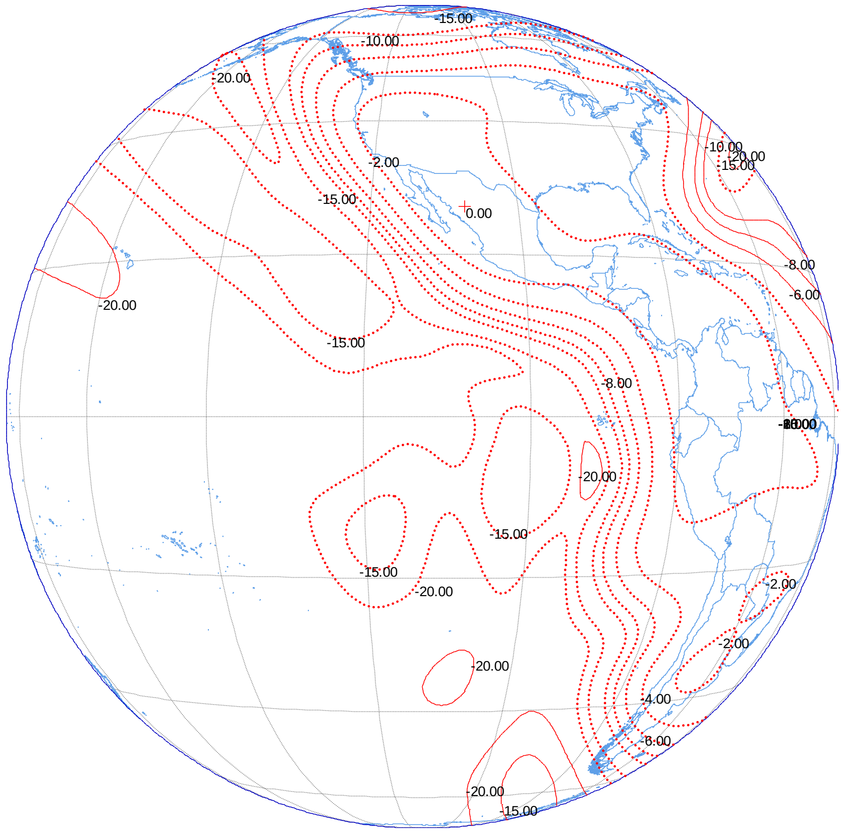


Figure 5-6: Satmex-6 G/T Contours (chuh.gxt)

The aggregate I/N across the 24 modelled FSS channels, averaged over 10 simulation iterations is shown in the figure below. The calculation includes RLANs in Mexico, Central America, North America, South America and the Caribbean.

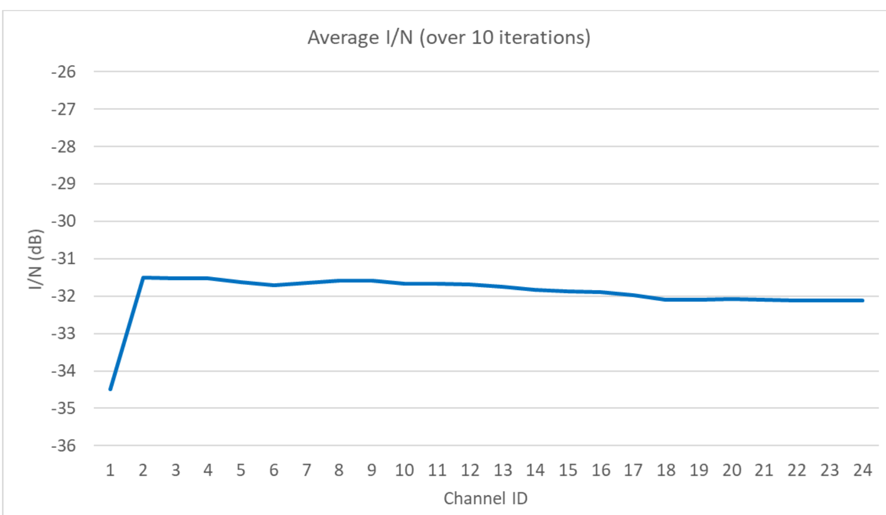


Figure 5-7: Satmex-6 I/N per channel

The maximum I/N found in a single iteration is -31.01 dB. The maximum averaged over 10 iterations is -31.50 dB.

5.1.3.4 SES-3 (103° W)

The SES-3 satellite at 103° west has a spot beam with a peak G/T of 5.3 dB/K. The G/T contours are shown below.

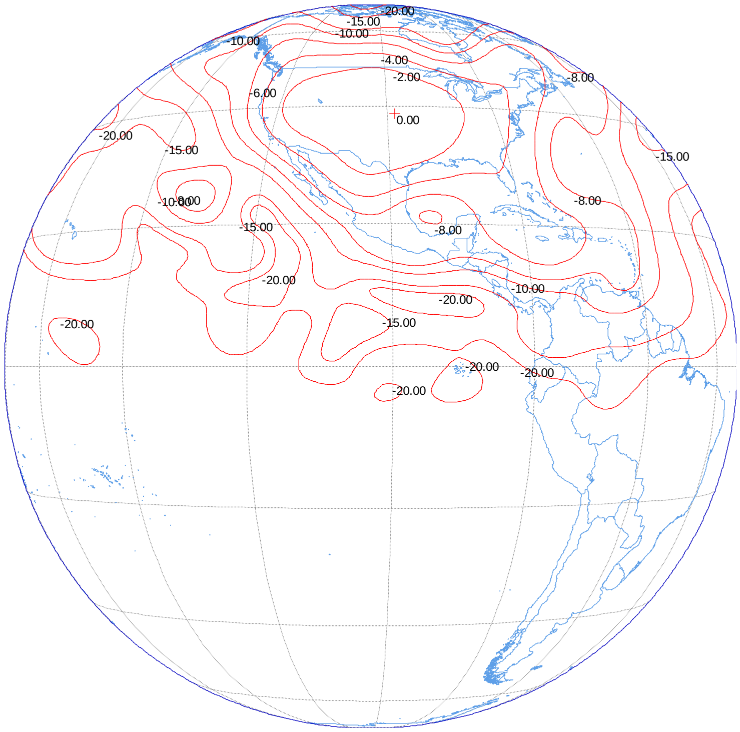


Figure 5-8:SES-3 G/T Contours (crv.gxt)

The aggregate I/N across the 24 modelled FSS channels, averaged over 10 simulation iterations is shown in the figure below. The calculation includes RLANs in Mexico, Central America, North America, South America, and the Caribbean.

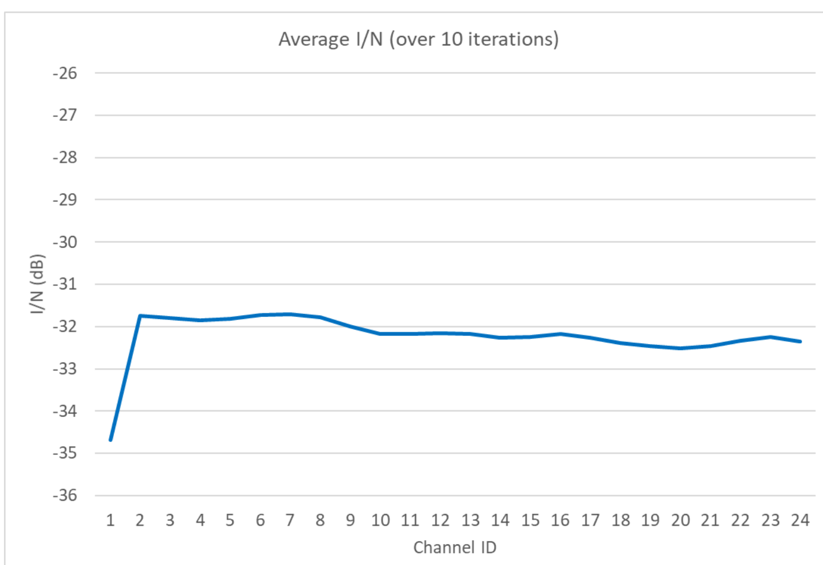


Figure 5-9: SES-3 I/N per channel

The maximum I/N found in a single iteration is -31.34 dB. The maximum averaged over 10 iterations is -31.71 dB.

5.1.3.5 Galaxy-19 (97° W)

The Galaxy-19 satellite at 97° west has a spot beam with a peak G/T of 4.6 dB/K. The G/T contours are shown below.

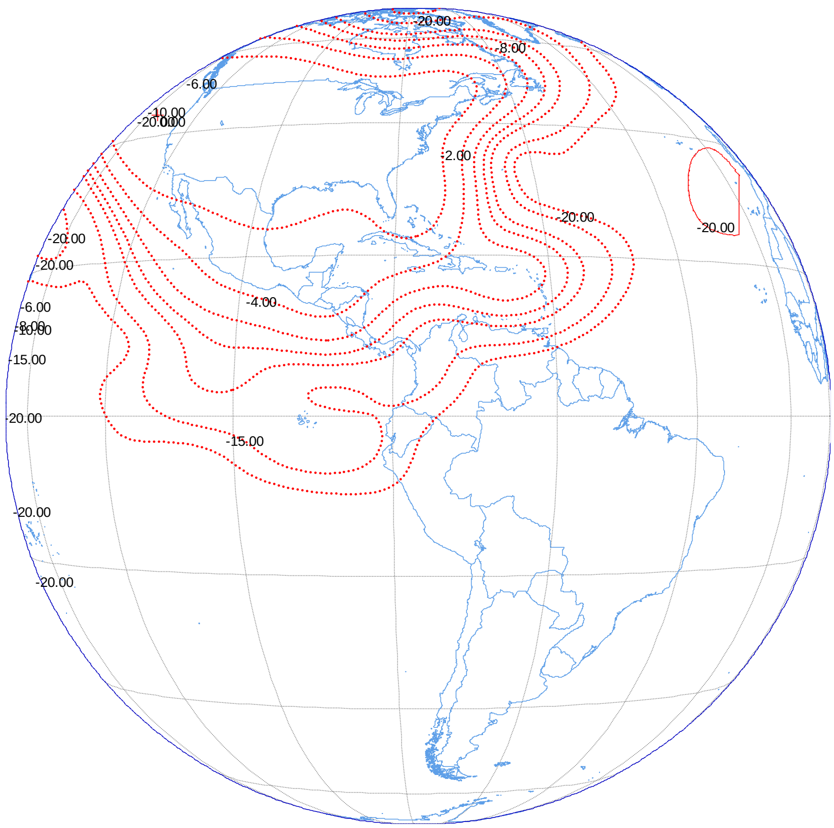


Figure 5-10:Galaxy-19 G/T Contours (crf_c.gxt)

The aggregate I/N across the 24 modelled FSS channels, averaged over 10 simulation iterations is shown in the figure below. The calculation includes RLANs in Mexico, Central America, North America, South America, and the Caribbean.

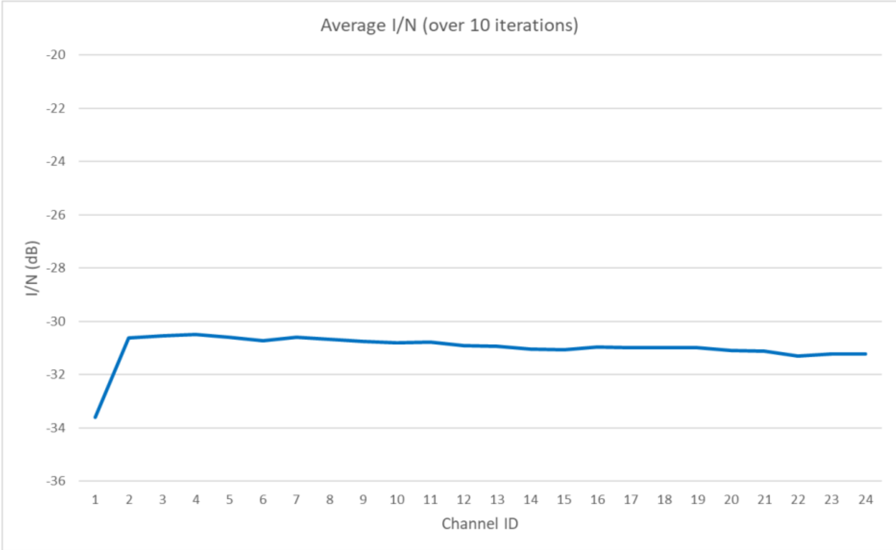


Figure 5-11: Galaxy-19 I/N per channel

The maximum I/N found in a single iteration is -29.73 dB. The maximum averaged over 10 iterations is -30.50 dB.

5.1.3.6 NSS-806 (47.5° W)

The NSS-806 satellite at 47.5° west has a hemispheric beam and a regional beam with a peak G/T of 3.1 dB/K. The G/T contours are shown below.

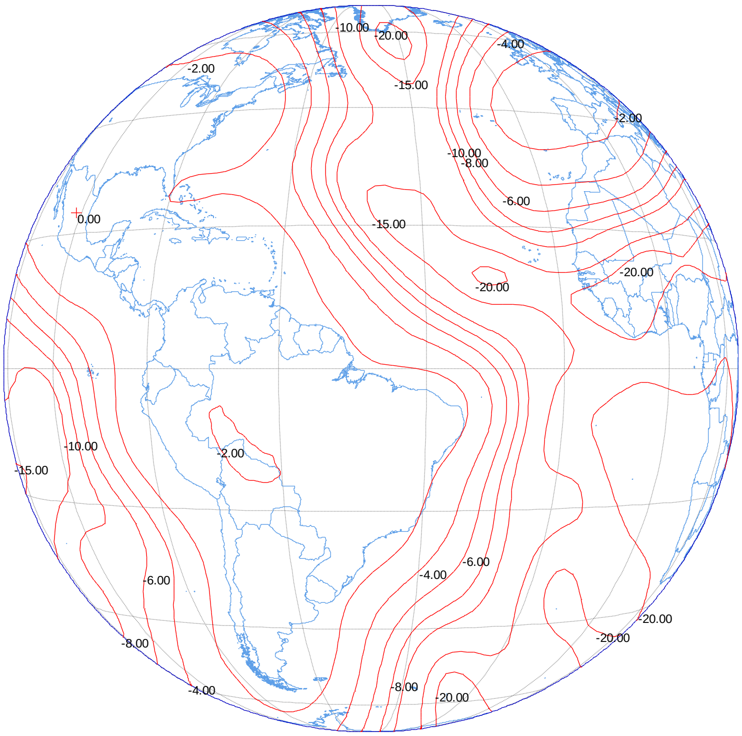


Figure 5-12: NSS-806 G/T Contours (hau.gxt)

The aggregate I/N across the 24 modelled FSS channels, averaged over 10 simulation iterations is shown in the figure below. The calculation includes RLANs in Mexico, Central America, North America, South America, the Caribbean, Europe and Africa.

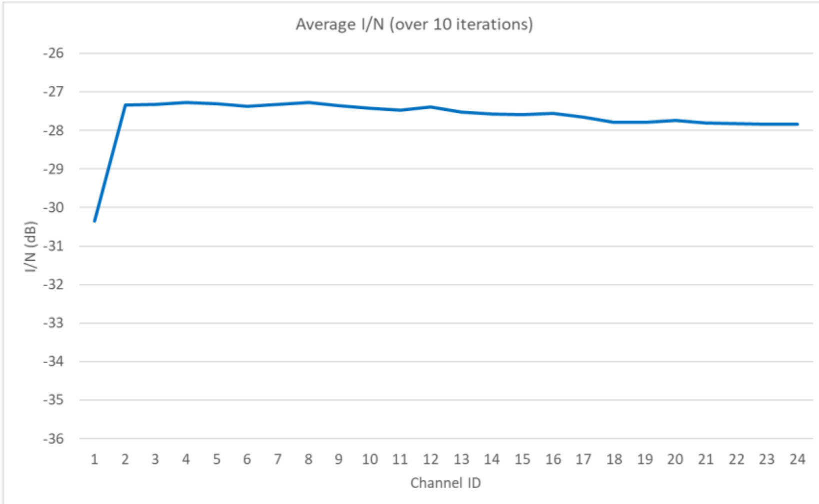


Figure 5-13: NSS-806 I/N per channel

The maximum I/N found in a single iteration is -26.92 dB. The maximum averaged over 10 iterations is -27.27 dB.

5.1.4 FSS Link Budgets

Table 5-3 shows aggregate link budget for Satmex 7 (Eutelsat 115 West-B) which has the highest peak G/T and the highest I/N levels after NSS-806.

As indicated in this table, the average Building Entry Loss, Clutter Loss, Free Space Path Loss and G/Ts are the averages over the values used by the Monte Carlo simulation amongst all the RLANs within the corresponding region. Averaging for the transmit powers and simulation parameters (building entry losses, clutter losses and G/T values) are done in linear domain. Note that this results in much lower building entry and clutter losses than their mean values, i.e. 50th percentile.

The link budgets match the Monte Carlo simulation results within about 3 dB for this satellite. The differences are due to the coarse approximation of the link budget versus the very detailed precise calculations in the Monte Carlo simulation.

Table 5-3 - Satmex 7 (at 114.9 West) link budget

Parameter	Unit	Mexico	The Americas (except Mexico) and the Caribbean	Source
Number of Active RLANs		179,261	1,194,849	Table 5-2
Number of Active RLANs contributing to I/N		179,162	604,121	RLANs within the coverage area
Total Average EIRP per RLAN	mW	69.80	69.80	Includes body loss for LPI and Standard Power Client devices per Section 3.2.2 and Average (in linear domain)

				far-field gain for VLP devices per Section 3.2.3
Average Building Entry Loss (Indoor RLAN)				
Traditional Building	dB	-17.91	-14.06	Simulation; Average in linear domain
Thermally Efficient Building	dB	-23.27	-21.44	
Total Aggregate Average EIRP (all RLANs)	dBW	27	34	Includes Building Loss
Bandwidth Correction		0.031	0.031	= Satellite Noise Bandwidth / Total RLAN Band (5945 to 7125 MHz)
Total Aggregate Average EIRP (bandwidth correction)	dBW	12	18	
Average Free Space Path Loss (FSPL)	dB	-199.97	-200.43	Simulation
Polarization Loss	dB	-3	-3	
Average Clutter Loss	dB	-0.62	-2.20	Simulation; Average in linear domain
Total Aggregate Interference Power at Satellite	dBW	-191.95	-187.16	
Satellite Receiver Antenna Peak G/T	dB/K	5.8	5.8	Not used;
Satellite Receiver Antenna Avg. G/T	dB/K	5.11	2.90	Simulation; Average in linear domain over the area
Boltzmann's Constant	dBW/K/Hz	-228.60	-228.60	
Satellite Noise Bandwidth	MHz	36.0	36.0	
Calculated Average I/N	dB	-33.80	-31.23	
Simulated Max I/N	dB	-34.12	-27.81	Simulation
"Calculated Average I/N" – "Simulated Max I/N"	dB	0.32	-3.42	

5.1.5 FSS Sharing Conclusions

Simulations show that in all cases studied, the I/N for all satellites in all channels is less than -26.92 dB. It can be concluded that RLANs in the three device classes operating over a 20, 40, 80, or 160 MHz channel bandwidth do not cause harmful interference to an FSS uplink in the 6 GHz band.

5.2 Fixed Service (FS) Sharing

This Section describes analyses performed to investigate the impact of RLAN interference on FS links.

A detailed Monte-Carlo simulation of the interference environment was performed for the FS in Mexico City for which the data was available. The accuracy of this data was not validated to confirm whether they represent real FS link. However, the data could represent potential FS links in this region.

The Monte-Carlo simulations were performed over a large number of independent events to establish long-term statistical properties in the environment.

5.2.1 FS Data

27 FS links in the vicinity of Mexico City were used in the simulation. Figure 5-14 to Figure 5-19 show the cumulative distribution function (CDF) of the FS characteristics that were used in the simulation, which were: FS Bandwidth, FS Rx peak Gain, FS Rx feederloss, FS Rx height above ground level, FS Rx AMSL[39] (Above Mean Sea Level) Height – FS Tx AMSL Height, and FS link

[39] Note that the simulation uses SRTM terrain height while Figure 5-18 shows AMSL height (height above ground level + terrain height) using terrain height in the FS data.

distance. These figures show the range of values as well as the median (50th percentile) values used. As indicated, this data can represent real FS links.

In addition to these parameters, the other parameters that were used from the FS data in the simulation were the FS Tx and Rx latitude and longitude, and FS center frequency. Figure 5-20 shows the location of the 27 FS Tx-Rx links in Google Earth. The numbers correspond to the 27 unique FS ID's.

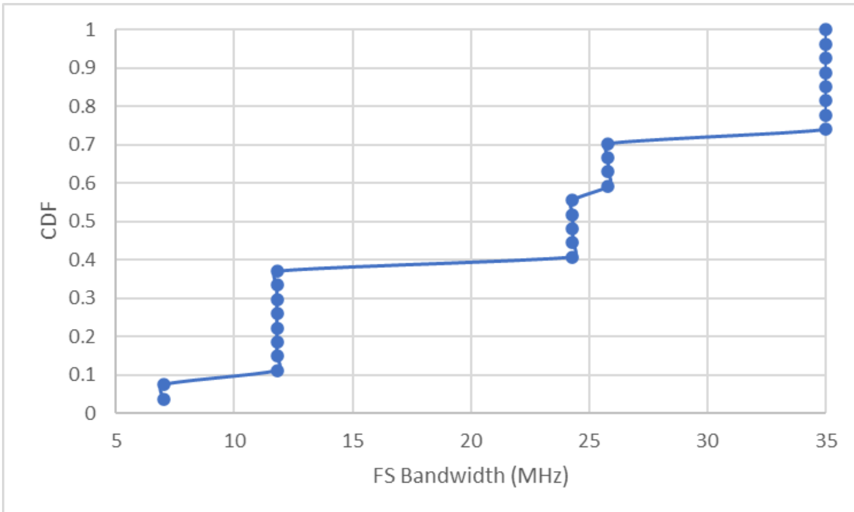


Figure 5-14 - CDF of FS Bandwidth for 27 FS simulated in vicinity of Mexico City

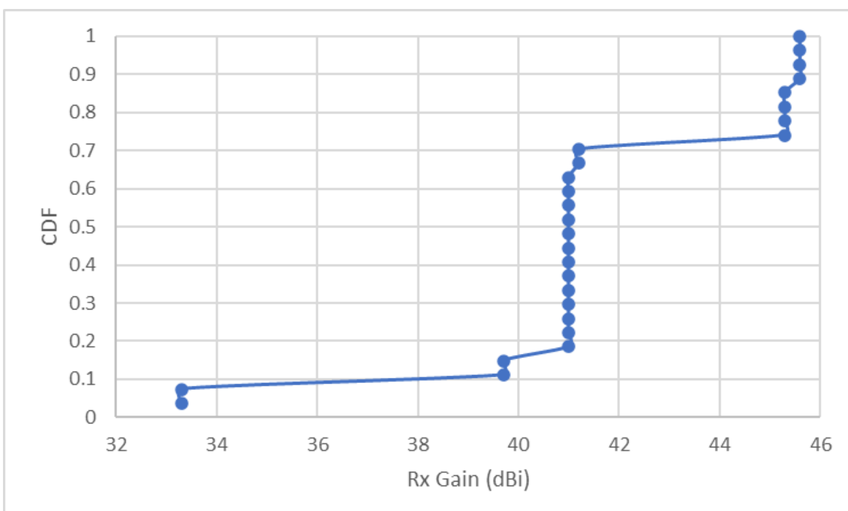


Figure 5-15 – CDF of FS Rx peak Gain for 27 FS simulated in vicinity of Mexico City

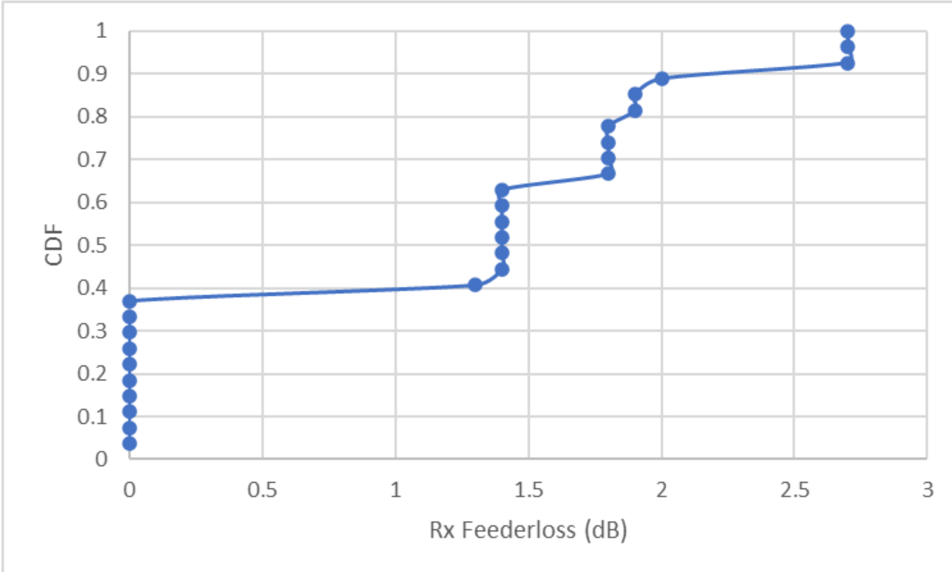


Figure 5-16 - CDF of FS Rx Feederloss for 27 FS simulated in vicinity of Mexico City

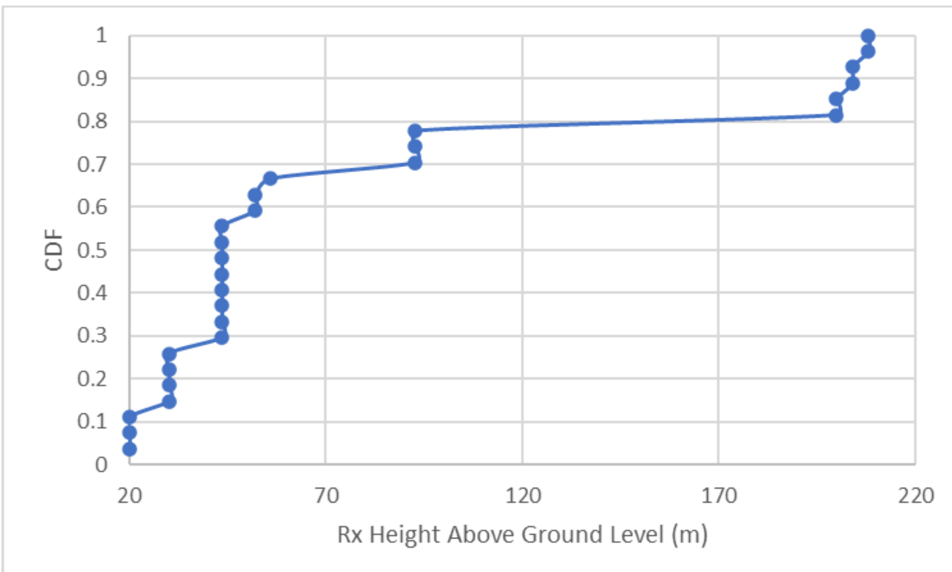


Figure 5-17 - CDF of FS Rx Height Above-Ground-Level for 27 FS simulated in vicinity of Mexico City

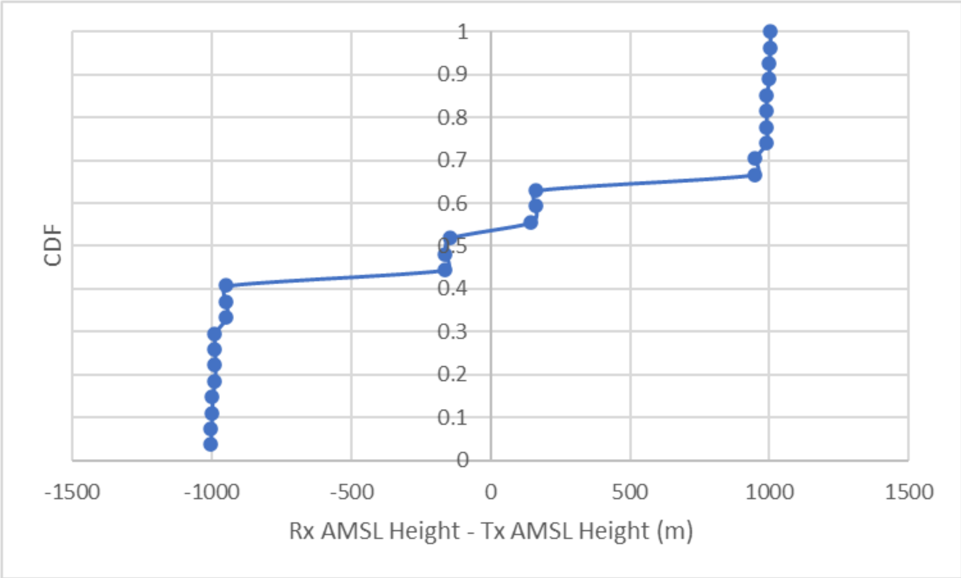


Figure 5-18 - CDF of (Rx AMSL Height – Tx AMSL Height) for 27 FS simulated in vicinity of Mexico City

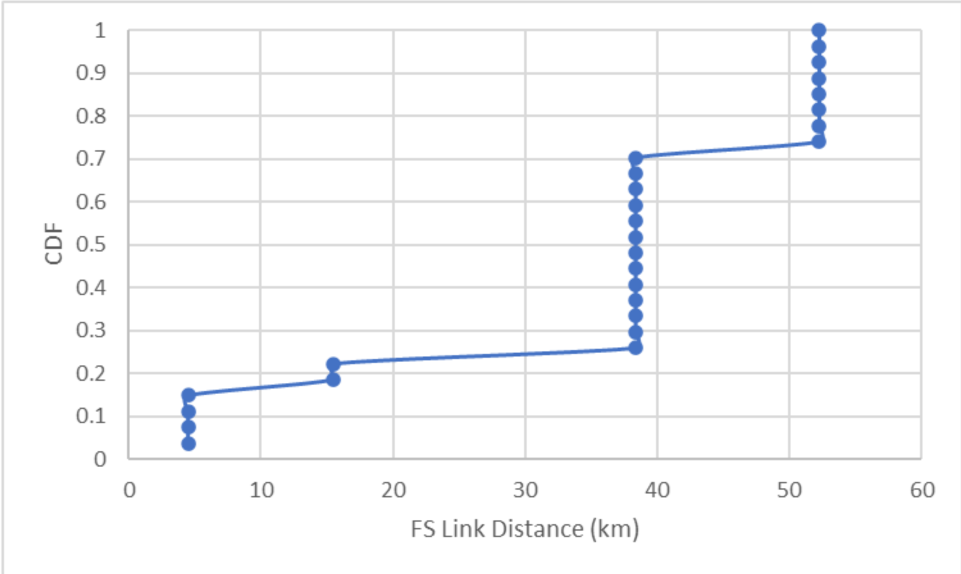


Figure 5-19 – CDF of FS link distance

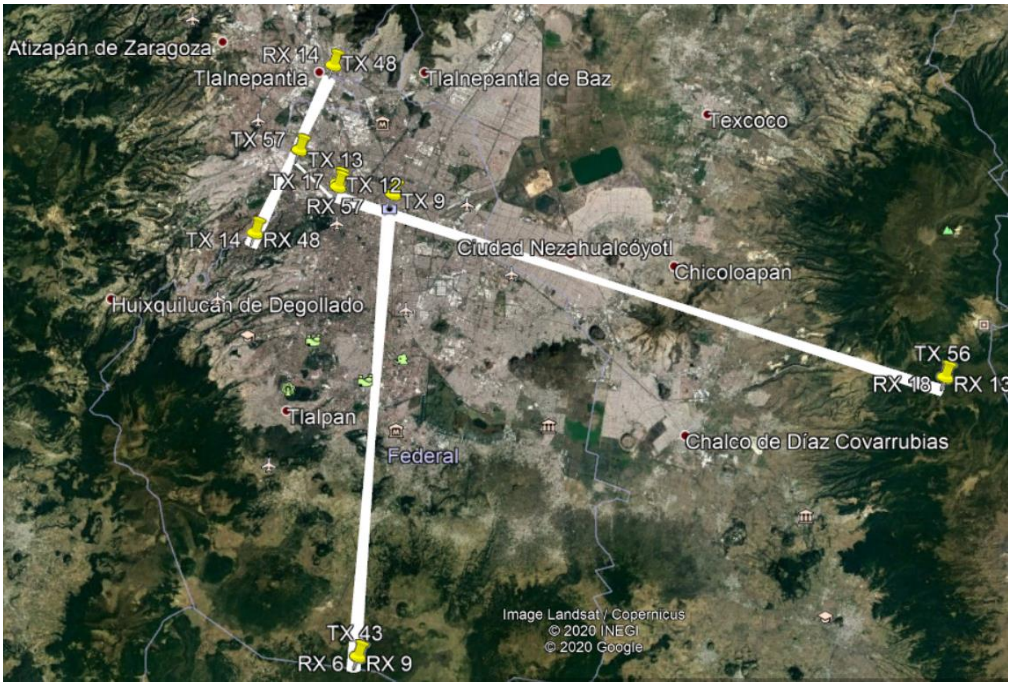


Figure 5-20 – Location of 27 simulated FS links (yellow markers at FS Tx and FS Rx and white 3dB beamcone from FS Rx to FS Tx)

5.2.2 Key Modeling Assumptions

5.2.2.1 RLAN Device Deployment

As described in Section 3.1.1, the RLANs were randomly distributed throughout Mexico based on population density. The drop process is detailed in Step 2 of Section 5.1.1.

5.2.2.2 FS Receiver Antenna Performance

ITU-R Recommendation F.1245[40] was used to model the FS antenna sidelobe performance. As shown in Figure 5-21, commercial antennas (such as UHX10 that is used by some of Mexico's FS), portrayed by the red line in the figure, significantly outperform F.1245. By using F.1245 this analysis overstates the interference and provides very conservative results.

40 International Telecommunication Union, *F.1245: Mathematical Model of Average and Related Radiation Patterns for Point-to-Point Fixed Wireless System Antennas for Use in Interference Assessment in the Frequency Range From 1 GHz to 86 GHz*, Recommendation F.1245 (2019), *available at* https://www.itu.int/rec/R-REC-F.1245/en.

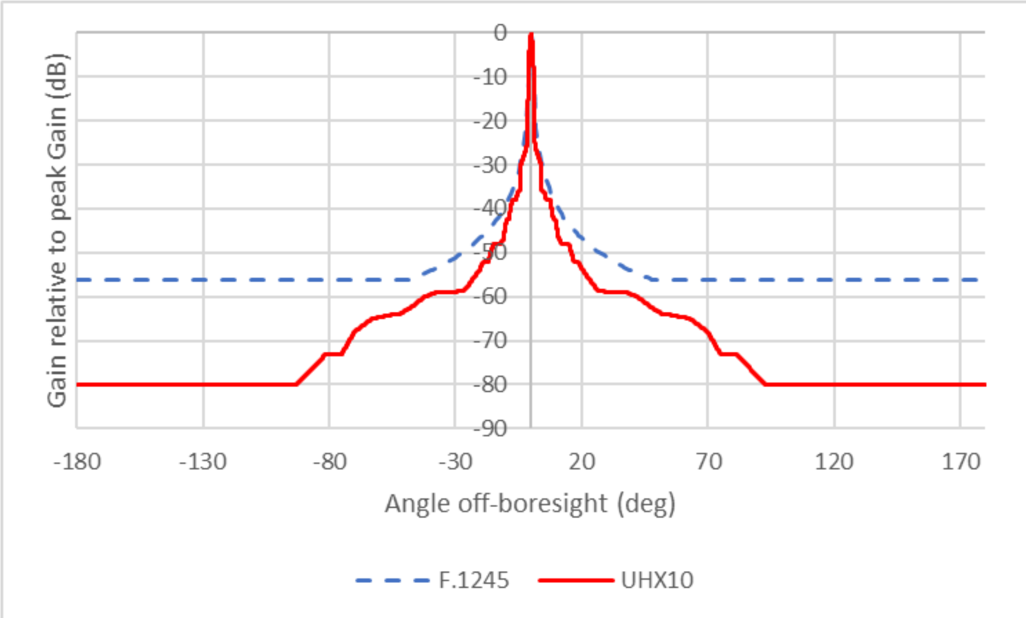


Figure 5-21 - Comparison of ITU-R 1245 and Ultra-High-Performance Antenna (UHX10) Radiation Patterns

5.2.2.3 FS Simulation Methodology

Monte-Carlo simulations were performed to calculate RLAN interference to each of the 27 FS stations in the vicinity of Mexico City. For each iteration, active RLANs were randomly placed, with their locations weighted according to the population density. The aggregate interference power to each of the FS stations were then calculated. One hundred thousand simulation iterations were then performed to gather statistics on the interference.

The interference power, *I*, is computed per Eqn. 5-2 below:

$$I = EIRP + G_{FarField} - L_{body} - L_{Bldg} - L_{PropagationPath} - L_{SpectralOverlap} - L_{Polarization} - L_{feed} + G_{Rx\text{-}to\text{-}RLAN} \quad (5\text{-}2)$$

where,

- *I* (dBW) = Interference Power from an RLAN device
- *EIRP* (dBW) = RLAN EIRP (Table 3-4 as weighted by Tables 3-7 and 3-8) for LPI and Standard Power; 14 dBm for VLP) within RLAN channel bandwidth (Table 3-9)
- $G_{FarField}$ (dB) = VLP far field gain that includes body loss (see Section 3.2.3); 0 dB for LPI and Standard Power RLANs
- L_{body} (dB) = LPI and Standard Power RLAN Body Loss (see Section 3.2.2); 0 dB for VLP
- L_{Bldg} (dB) = Building Entry Loss
- $L_{PropagationPath}$ (dB) = Propagation Path loss including Clutter loss (Section 4.1)

- $L_{SpectralOverlap}$ (dB) = 10*log10(spectrum overlap between VLP channel and victim channel / VLP bandwidth), also called frequency-dependent rejection.
- $L_{polarization}$ = Polarization Loss of 3 dB[41,42]
- L_{feed} (dB) = Feederloss of victim FS receiver (per FS data)
- $G_{Rx\text{-}to\text{-}RLAN}$ (dBi) = Gain of victim FS Rx towards RLAN based on the angle off-boresight

The I/N is the ratio of the interference power and the receiver (Rx) noise power. The receiver noise power is calculated, for each victim Rx, using Eqn. 5-3 below:

$$N = 10(kT_0B) + NF \text{ (dBW)} \quad (5\text{-}3)$$

where,

- N = Victim FS Rx noise power at receiver input (dBW)
- k = Boltzmann's constant = $1.38064852 \times 10^{-23}$ m^2 kg s^{-2} K^{-1}
- $T_0 = 290$ K
- B = Victim Rx Bandwidth (Hz)
- NF = Victim FS Rx Noise Figure (dB) = 4 dB (per FS data)

Note that Noise Figure of 4 dB is conservative. For example, in the co-existence studies conducted by the EU 5dB Rx Noise Figures was considered.

For each FS in the simulation, this I/N is aggregated over all RLANs.

Next, for these FS stations, the resulting increase in FS unavailability was calculated and analyzed.

5.2.3 Aggregate Interference Simulation

One hundred thousand simulation iterations were performed to determine the aggregate I/N at each of 27 FS receive locations. Together these simulations represent 2,700,000 different RLAN-to-FS interference morphologies with more than 17.92 billion total number of active RLANs dropped in Mexico City, which represent an excellent statistical model of expected interference. The occurrence probability for aggregate I/N > -6 and 0 dB was computed. To ensure inclusion of every RLAN that could affect a receiver, while avoiding the unnecessary complexity of modeling every RLAN in

[41] International Telecommunication Union, *Working Document Towards a Preliminary Draft New Report ITU-R M.[RLAN SHARING 5150-5250 MHZ] - Sharing and Compatibility Studies of WAS/RLAN in the 5 150-5 250 MHz Frequency Range*, Appendix 2, Section 5.1.6.7 (Nov. 2017) (noting that with regard to polarization mismatch, a value of 3 dB is considered according to what has been supported by France during TG-5.1), *available at* https://www.itu.int/md/R15-WP5A-171106-TD-0236/en.

[42] VLP on-body device measurements were made with two orthogonal polarized detectors and the combined total gain reported. These antennas are roughly circularly polarized, whereas traditionally FS microwave stations employ linear polarization. Thus, an average polarization loss of 3 dB is reasonable.

Mexico for every receiver, all RLANs operating within 150 km of the receiver were considered in the calculation.

Figure 5-22, Figure 5-23, and Table 5-4 show the probability of I/N (aggregated over the aforementioned morphologies) exceeding an I/N level (x-axis) due to the deployed active RLANs. Of the 2,700,000 different RLAN-FS morphologies simulated, the aggregate I/N for an FS receiver exceeded -6 dB in 0.209% of instances. Further investigation into these instances revealed that majority of them were caused by a single RLAN. Further, of these single-entry I/N > -6 dB occurrences, over half were due to an RLAN in the main beam[43] and 19% were due to an RLAN in the main beam of the FS receiver and less than 1 km from the FS receiver. Furthermore, there are additional topologies that resulted in a single RLAN device causing an I/N value greater than -6 dB such as: outdoor RLAN devices, indoor RLAN devices with very small building penetration loss, RLAN with minimal loss in the far-field gain (VLP), and RLAN devices having small path loss values that are statistically in the tail of the path loss probability distribution function. For all the threshold exceedance instances analyzed, none had a significant impact on FS link availability (*see* section 5.2.4).

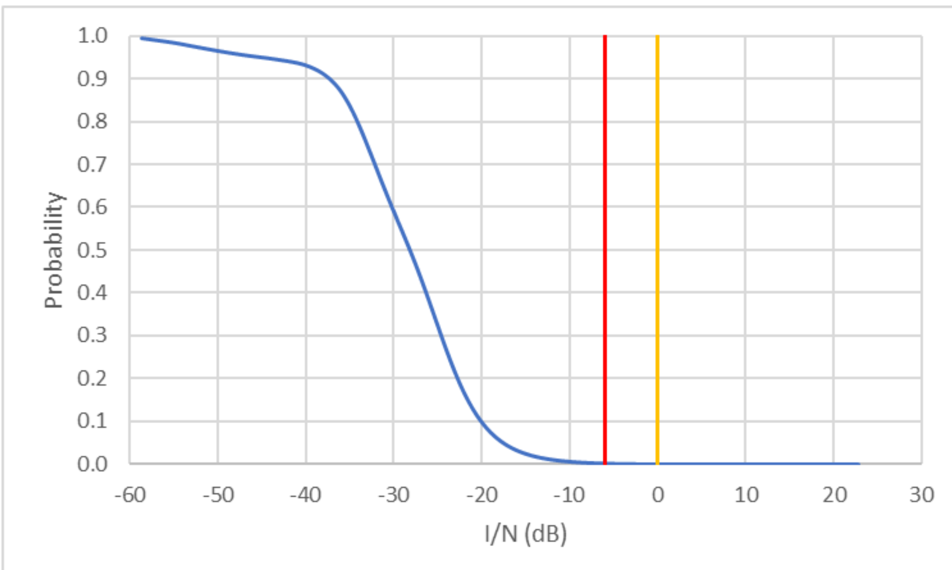


Figure 5-22 - Probability of Aggregate RLANs I/N Exceeding I/N Values on X-axis for 2,700,000 RLAN-FS morphologies (27 FS/iteration x 100,000 iterations)

[43] An RLAN was considered as being "in FS receiver's main beam" if it was within FS receiver's 3dB beamwidth, which corresponded to the RLAN being at an angle off-boresight from the FS receiver as large as 1.8° for these FS.

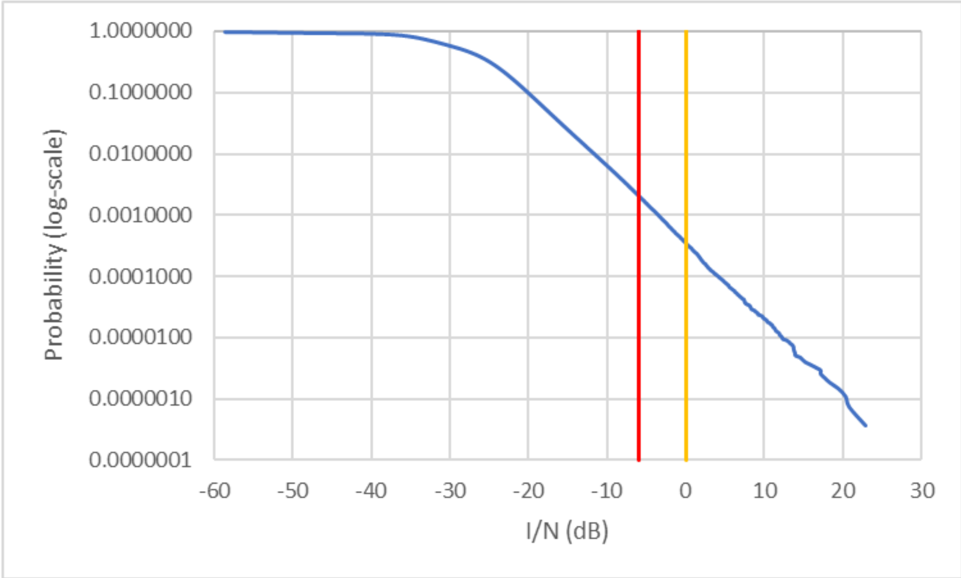


Figure 5-23 - Probability of Aggregate RLANs I/N Exceeding I/N values on X-axis for 2,700,000 RLAN-FS morphologies (27 FS/iteration x 100,000 iterations) Zoomed In

Table 5-4 - Interference statistics from 100,000 Independent Simulations of FS in Mexico City

I/N threshold (dB)	Aggregate
-6	0.209%
0	0.035%

5.2.4 FS Availability Analysis

The availability analysis assumed a typical FS design target of 99.999% availability (unavailability=0.001% corresponding to 5.3 minutes/year). Results are compared to a target increase in unavailability of less than 10%, as established by the ITU,[44] that is sufficient to allow continued robustness of FS links.

The increase in unavailability due to RLAN interference was further analyzed, using a two-step process, by looking at the 27 FS stations and at the specific impact on unavailability due to RLAN devices.

First, a fade margin required to achieve the target availability of 99.999% was determined using ITU-R Rec. P.530-17 (P.530). Then, the increase in unavailability in the presence of interference was assessed.

Second, if an FS link's unavailability increased more than 10% in Step 1, the actual operating parameters were examined to determine the available fade margin. These links were then reassessed to determine if they would meet the 10% target.

The fade margin probability density function (pdf) is obtained from P.530 (section 2.3.2 Eqn. 18) using FS unavailability and the multipath occurrence factor, p_0. p_0 provides the fade margin required for the

[44] International Telecommunication Union, *F.1094-2: Maximum Allowable Error Performance and Availability Degradations to Digital Fixed Wireless Systems Arising from Radio Interference from Emissions and Radiations from Other Sources* (2007), *available at* https://www.itu.int/rec/R-REC-F.1094/en.

average worst month and is computed using P.530 (section 2.3.2, Eqn. 11), with input parameters from the FS data. The input parameters are the FS Transmitter (Tx) and Receiver (Rx) terrain height, antenna height above ground level, link distance, and center frequency.

Given the fade margin pdf and the pdf of the degradation due to RLAN interference for a specific FS (i.e., (I+N)/N from the 100,000-iteration simulation), the impact on FS link unavailability can be determined directly from the combined distribution. The convolution provides the correct answer to this question under the assumption that the two random variables (fading and interference) are independent. This independence is a conservative approximation. In fact, there is an inverse relationship between RLAN device activity and when multipath fading occurs. As multipath fading occurs between midnight and 8 am,[45] while RLAN usage will primarily be from 7pm to 10pm (for LPI and Standard Power devices) or during daylight (for VLPs). This inverse correlation means that the sum of interference and fading is statistically smaller than what is modeled.

Furthermore, for accuracy, the full I/N distribution is used in the analysis including all aggregate interference events.

In Step 1, results showed that the 10% unavailability target was met for 8 FS (out of 27). The increase in unavailability for these 8 FS is shown in Figure 5-24. As indicated, these FS had less than 2.4% increase in unavailability.

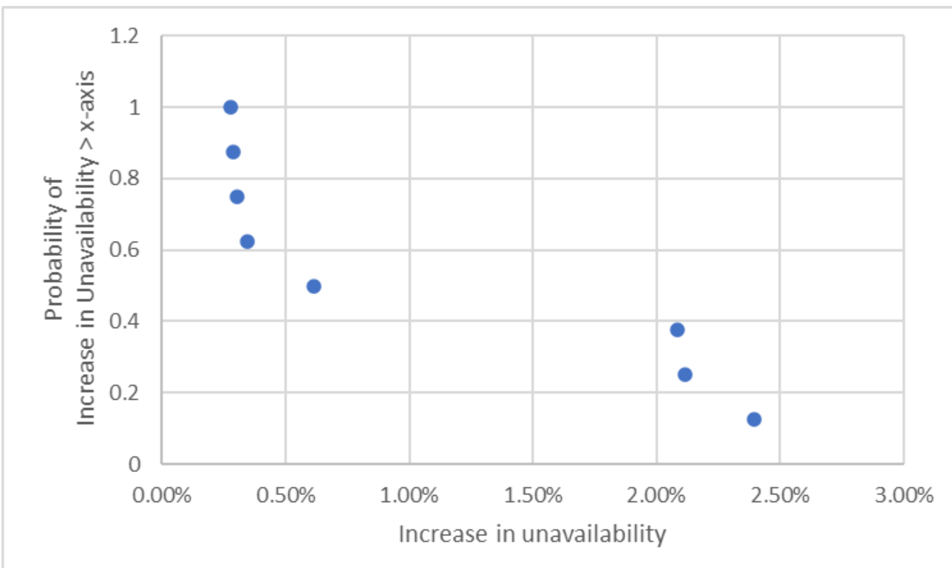


Figure 5-24 – Increase in unavailability for 8 FS that meet the 10% target.

The analysis in Step 1 assumes that each FS link has the exact margin to achieve the target availability. However, given that amplifiers and antennas only come in certain sizes, it is unlikely that these links achieve this margin exactly. In Step 2, the 19 links that failed to meet the 10% unavailability target are examined more closely. As indicated below, after considering the actual FS link operating parameters at the links' modulations in Step 2, they all meet the 10% target.

45 *See* NTIA Report 05-432.

These 19 FS all had very small p_0's (2.3x10^{-6} to 0.007) that resulted in very low fade margins (5.3 to 12.5 dB), which made them sensitive to interference. Those with < 0.001 p_0 are also short-haul links (≤ 15.5 Km) which have higher link margins and can generally accept interfering signals 1-10 dB or more above long-haul performance requirements and not affect long-term performance.[46]

Table 5-5 shows the link characteristics of these FS stations.

Table 5-5 - Link characteristics of the FS with Increase in Unavailability > 10% using theoretical link characteristics

FS ID	FS Tx EIRP (dBm)	FS Tx Power (Watt)	FS link distance (km)	Received C/N (dB) (Eqn. 5-4)	Multipath occurrence factor, p_0 (ITU-R P.530)
2	42.16	0.00	38.39	42.71	0.002
4	42.16	0.00	38.39	42.48	0.002
6	52.494	0.03	38.39	47.97	0.002
8	62.66	0.15	38.39	63.30	0.002
9	52.494	0.03	38.39	48.05	0.002
10	42.16	0.00	38.39	42.63	0.002
12	68.4	0.72	4.49	81.99	2.26E-06
14	61.4	1.00	15.48	63.70	0.001
17	74.2	1.07	52.28	69.05	0.007
23	69.96	1.68	4.49	82.15	2.26E-06
36	42.16	0.00	38.39	42.36	0.002
38	42.16	0.00	38.39	42.13	0.003
39	51.897	0.02	38.39	46.37	0.002
40	51.897	0.02	38.39	46.22	0.002
42	62.66	0.15	38.39	62.94	0.002
44	42.16	0.00	38.39	42.28	0.003
46	68.4	0.72	4.49	81.56	2.33E-06
48	61.4	1.00	15.48	63.26	0.001
57	70.66	1.68	4.49	81.72	2.33E-06

The FS data information was used to compute the C/N at the receiver, shown in Table 5-5, using Eqn. 5-4 below:

$$\frac{C}{N}(dB) = EIRP\ (dBW) - FSPL\ (dB) - L_{feed}\ (dB) + G_R\ (dBi) - N\ (dBW) \qquad (5\text{-}4)$$

where,

- EIPP (dBW) = FS EIRP from the FS data

[46] National Telecommunications and Information Administration, *Interference Protection Criteria Phase 1 - Compilation from Existing Sources*, NTIA Report 05-432, 4-8, 4-9 (2005), https://www.ntia.doc.gov/files/ntia/publications/ipc_phase_1_report.pdf ("NTIA Report 05-432").

- FSPL (dB) = 92.45 + 20*log10(FS link distance [km]) + 20*log10(center frequency [GHz])
- L_{feed} = FS Rx Feederloss from the FS data
- G_R = FS Rx Gain (dBi) from the FS data
- N = Noise Power (dBW) = -228.6 dB(W/K/Hz) + 10*log10(T) + Noise Figure + 10*log10(B [Hz])
- T = System temperature = 290 K
- Noise Figure = 4 dB from the FS data
- B = FS channel bandwidth (Hz)

The actual FS fade margin, F_a, is then computed as shown in Eqn. (5-5).

$$F_a \text{ (dB)} = C/N \text{ (dB)} - \text{(max) } C/Nreq \text{ (dB)} \quad (5\text{-}5)$$

The modulations in the FS data for the 19 FS links were: Analog Modulation, 64QAM, 128QAM or 256QAM.

Table 5-6 shows C/Nreq values obtained from several manufacturers' datasheets. The 30 MHz channels have a range of values that indicate different coding and receiver performance. For the analysis, the maximum C/Nreq values are used (indicated in **bold**). This will provide the most conservative answer.

Note that the 19 FS have the following bandwidths for each modulation. For the FS bandwidths unavailable in manufacturers' datasheets, the closest lower bandwidth is chosen as indicated below for conservativeness.

- Analog Modulation: 11.8 and 24.3 MHz → 10 and 20 MHz
- 64-QAM: 7 and 24.3 MHz → 7 MHz
- 128-QAM: 35 MHz → 30 MHz
- 256-QAM: 25.8 MHz → 20 MHz

Furthermore, for Analog Modulation, the C/Nreq for 64-QAM modulation was chosen for conservativeness.

Table 5-6 - SNR required used for the 19 FS based on the link's modulation and bandwidth

Modulation	Bandwidth (MHz)	C/Nreq (dB)	Manufacturers
64-QAM	30	16.7 – **20.7**	SAF Integra, Redline RDL 5000, and ALFOplus[47]
128-QAM		19.7 – **24.2**	
64-QAM	7	22.5	SAF Integra

[47] *See* SAF Tehnika, *SAF Integra Datasheet*, https://www.ispsupplies.com/content/datasheets/Integra%20series%20DS%20v1.43.pdf; Redline Communications, *RDL-5000 Datasheet*, https://rdlcom.com/wp-content/uploads/Redline-DS-RDL-5000.pdf; SIAE Microelettronica, *ALFOplus2 Datasheet, available at* https://www.siaemic.com/index.php/products-services/telecommunication-systems/microwave-product-portfolio/alfo-plus2.

64-QAM	10	20.5	SAF Integra
64-QAM	20	17.0	Redline RDL 5000
256-QAM	20	23.5 (strongFEC[48]) **27.0** (weakFEC)	Redline RDL 5000

Table 5-7 summarizes the key performance parameters for each link including the Fade Margin (FM) at the 99.999% availability target, the received C/N (Eqn. 5-4), C/Nreq (from Table 5-11), and F_a (Eqn. 5-5). The actual link fade margin is then compared to the FM at 99.999% availability and the difference is the "Actual Margin Above FM" (column C5). Notice the calculated "Actual Margin above FM" is very high for these links (>10.95 dB).

In addition, Table 5-7 includes the three FS (see Figure 5-24) that met 10% increase in unavailability but not 1% in the last 3 rows.

Next, the additional margin to meet the 10% target is determined and is shown in column C6.

Finally, the "Actual Margin above FM" (C5) is compared against the "Increase in FS link margin to meet the 10% target" (C6). The results show that the actual operating parameters on these 19 links led to more than sufficient margin to meet the 10% target.

To further demonstrate the robustness of this analysis, 1% increase in unavailability was studied as a sensitivity analysis and shown in column C7. As indicated in (C6) and (C7), the overall interference risk from RLAN operations is so low that nearly the same margin is necessary to achieve both 10% and 1% increase in unavailability.

This shows that all the 27 FS links meet the 10% increase in unavailability target as well as the sensitivity analysis down to 1% increase in unavailability.

*Table 5-7 - FS with Increase in Unavailability > 1% had **"Actual Margin beyond FM" (C5) >> "Increase in FS Link Margin to meet 10% target (C6) and 1% sensitivity (C7)"***

FS ID	**FM (dB) @ 99.999%**	**Received C/N (dB) (Eqn. 5-4)**	**C/Nreq (dB)**	**F_a (dB) (Eqn. 5-5)**	**Actual Margin (dB) above FM**	**Increase in FS Link Margin (dB), x, to meet 10% target**	**Increase in FS Link Margin (dB), x, to meet 1% (sensitivity)**
Column	**C1**	**C2**	**C3**	**C4=C2-C3**	**C5=C4-C1**	**C6**	**C7**
2	10.57	42.71	20.5	22.21	11.65	0.70	0.79
4	10.60	42.48	20.5	21.98	11.38	4.05	4.05
6	10.50	47.97	17	30.97	20.47	0.55	0.65
8	10.56	63.30	20.5	42.80	32.25	0.14	0.26
9	10.49	48.05	17	31.05	20.56	2.04	2.04
10	10.58	42.63	20.5	22.13	11.55	0.42	0.53
12	5.32	81.99	27	54.99	49.67	11.96	12.86
14	8.70	63.70	22.5	41.20	32.50	4.95	4.95
17	12.34	69.05	24.2	44.85	32.52	4.85	4.85
23	5.32	82.15	27	55.15	49.83	9.28	9.92
36	10.65	42.36	20.5	21.86	11.21	5.20	5.20

[48] FEC = Forward Error Correction Coding

38	10.68	42.13	20.5	21.63	10.95	5.42	7.03
39	10.56	46.37	17	29.37	18.80	2.76	2.76
40	10.58	46.22	17	29.22	18.63	0.44	0.54
42	10.64	62.94	20.5	42.44	31.80	5.77	10.15
44	10.66	42.28	20.5	21.78	11.12	5.93	6.51
46	5.33	81.56	27	54.56	49.23	13.80	14.10
48	8.74	63.26	22.5	40.76	32.02	7.50	10.07
57	5.33	81.72	27	54.72	49.39	3.61	3.65
13	12.36	69.25	24.2	45.05	32.69	N/A[49]	0.03
18	12.36	71.41	24.2	47.21	34.84	N/A	0.03
22	12.35	71.21	24.2	47.01	34.67	N/A	0.02

5.2.5 FS Sharing Conclusions

To assess the interference impact from RLAN devices to FS stations, 100,000 Monte-Carlo simulation iterations were run for 27 FS in the vicinity of Mexico.

The simulation results indicated low average I/N > -6 dB and 0 dB occurrence probabilities of 0.209% and 0.035% respectively.

To accurately assess the impact of RLAN interference on FS performance, the increase in FS unavailability was computed for all 27 FS. The increase in FS unavailability analysis showed that using ITU derived fading distributions and considering the operating parameters of the FS, the increase in unavailability did not exceed the 10% target and the 1% sensitivity threshold for all 27 FS.

In conclusion, RLANs in the three device classes operating over a 20, 40, 80, or 160 MHz channel bandwidth do not cause harmful interference to an FS uplink.

5.3 MSS Gateway Coexistence

This Section describes analyses performed to examine the risk of harmful interference to the earth station antenna at the sole MSS gateway site, under construction, for each of the three RLAN device classes and the total number of RLAN devices. The analysis specifically addresses item number 14 in Table 2 of the IFT reference document - MOBILE SATELLITE SERVICES MÉXICO, S. DE R.L. DE C.V. Mobile Satellite Services Mexico is authorized to operate a constellation of non-geostationary low earth orbit (‘LEO’) satellites of the MSS, which use the frequency segment 6875-7075 MHz for its downlink links from the satellite constellation to roughly two dozen FSS receive sites (referred to in this document as MSS gateways) around the world.

There are two MSS satellite constellations on file with the ITU. They are HIBLEO-4FL and HIBLEO-X. Each constellation consists of 24 satellites with 3 satellites per orbital plane and 8 orbital planes. HIBLEO-4FL is the older of the two constellations. The downlink from the satellite to the MSS gateway site operates on 6875-6877.25 MHz. The space-to-earth downlink in the replacement constellation, HIBLEO-X, can operate between 6875-7075 MHz. Due to its much larger nominal frequency range, the simulation uses only the 24 satellites in the HIBLEO-X satellite network.

[49] 10% availability was met for this FS.

5.3.1 MSS Gateway Characteristics

The geo-coordinates the MSS gateway earth station was provided by IFT from licensing information on file. Once completed, the site will be the only MSS gateway in Mexico. The site is located in an isolated valley north and west of Mexico City in Jocotitlan, State of Mexico. A terrain map taken from Google Maps is presented below.

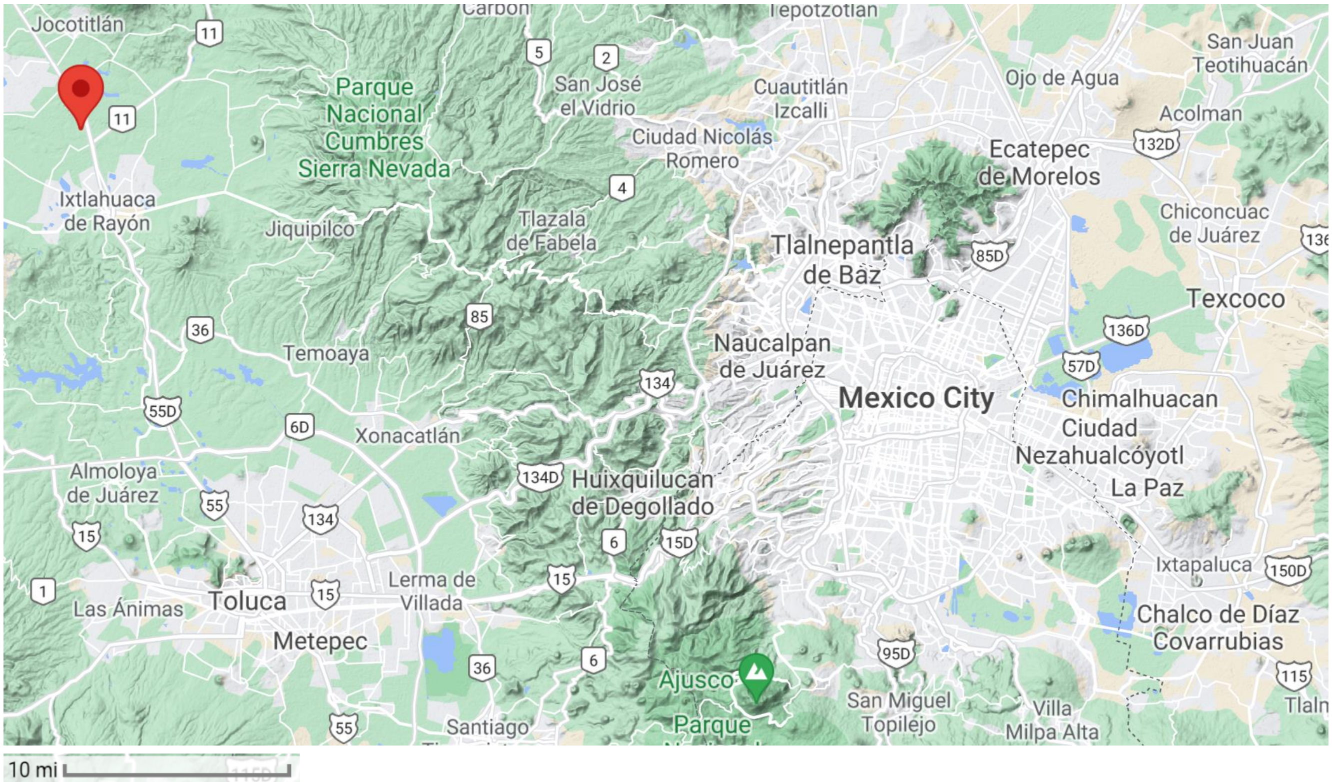


Figure 5-25 – Terrain Map of MOBILE SATELLITE SERVICES MÉXICO, S. DE R.L. DE C.V Gateway Site Within Central Mexico

A closer look at the immediate area around the MSS gateway site using Google Maps shows there is limited development. Presumably, this was one of the reasons for the site being selected for the new MSS gateway.

Figure 5-26 – Local Area Surrounding MSS Gateway Site (earth station antenna location noted in red)

A close up of the MSS gateway site shows that once completed there will be four earth station antennas. Based on earth station antenna deployments at MSS gateways in the United States and Canada, only the uppermost antenna appears to be in its final location. For this reason, the simulations use the coordinates and characteristics of uppermost antenna.

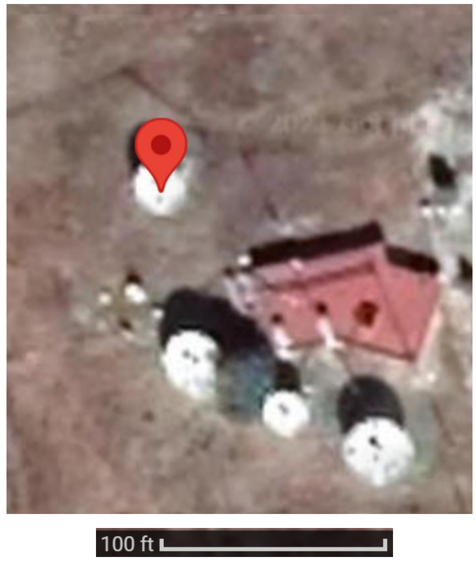


Figure 5-27 – MSS Gateway Site Under Construction

The MSS gateway characteristics used for the Monte Carlo simulation are provided below.

Table 5-8 – MSS Gateway Characteristics

Parameter	Value	Comments
Number of Antennas	**1**	
Latitude	**19.63266, -99.785807**	
Longitude		
Antenna Pattern	ITU-R S.465-6	Per License
Antenna Diameter	5.5 meters	Per license
Gain	**50.2 dBi**	
System Noise Temp (T in KTB) (includes feederloss)	**186.2087 K** = 10^((50.2 – 27.5 (G/T))/10) **Noise Figure = -1.92398 dB**	
Frequency Channel	6875 – 7055 MHz (180 MHz bandwidth)	One CDMA carrier (per license)
Elevation angle	Randomly chosen from a generated distribution	TBD
Polarization	Circular	
AGL Height	4 meters	

5.3.2 RLAN Device Characteristics

As the analysis examines the potential risk of harmful interference from each class of RLAN device, the number of units in each class must be determined. For the Monte Carlo studies on FSS and FS in the previous sections, the aggregate number of indoor and outdoor RLAN units were considered. The only difference in the assumptions from the previous studies is that in this instance, the number of

RLAN units are separated by RLAN class in order to derive the percentage (and number) of RLAN units for each.

Table 5-9 – Percentage of RLAN Units by Regulatory Class

RLAN Class	Units (percent)		
	Indoors	Outdoors	Total
LPI and LPI Clients	79.56	--------	79.56
Standard Power and Clients	8.44	1	9.44
VLP	10	1	11
Total	98	2	100

Note that the sum of the number of LPI and Standard Power units remains 88 percent, which is same as before. In addition, separate EIRP distributions for LPI and indoor standard power devices were generated. A table of the revised weighted EIRP distributions for LPI and Standard Power devices used in the simulations are presented below.

Table 5-10 – Revised LPI and Indoor Standard Power EIRP Distribution

Revised - LPI	Weighted EIRP Distribution (mW)								
Indoor Use Case	**Weight**	**4000**	**1000**	**250**	**100**	**50**	**13**	**1**	**Total**
Client (LPI)	24.10%	0%	0%	0%	1.08%	10.68%	12.34%	0%	24.10%
Consumer AP (LPI)	66.31%	0%	0%	7.90%	2.76%	11.20%	38.94%	5.51%	66.31%
Sub-Total	**90.41%**	**0.00%**	**0.00%**	**7.90%**	**3.84%**	**21.88%**	**51.28%**	**5.51%**	**90.41%**
Distribution		**0.00%**	**0.00%**	**8.74%**	**4.24%**	**24.21%**	**56.72%**	**6.09%**	**100.00%**

Revised - Indoor SP	Weighted EIRP Distribution (mW)								
Indoor Use Case	**Weight**	**4000**	**1000**	**250**	**100**	**50**	**13**	**1**	**Total**
Client (SP)	2.22%	0%	0%	0%	0.74%	1.35%	0.13%	0%	2.22%
Enterprise AP (SP)	2.63%	0%	0%	1.06%	0.90%	0.58%	0.08%	0.01%	2.63%
High-Performance Gaming Router (SP)	4.74%	0.67%	0.42%	1.43%	1.01%	0.83%	0.34%	0.04%	4.74%
Sub-Total	**9.59%**	**0.67%**	**0.42%**	**2.49%**	**2.65%**	**2.76%**	**0.55%**	**0.05%**	**9.59%**
Distribution		**6.98%**	**4.38%**	**25.96%**	**27.67%**	**28.72%**	**5.77%**	**0.52%**	**100.00%**

5.3.3 MSS Simulation Methodology

A Monte-Carlo simulation with 100,000 iterations was run to characterize the interference from the three classes of RLANs (LPI, VLP and Standard Power) to the earth station antenna at MSS gateway location. The RLANs were dropped per the methodologies and operating assumptions described in Section 5.2 for sharing with the FS links. This resulted in a total of 4.8 billion (or 4,803,200,000) RLAN drops within 150 km of the earth station antenna at the MSS gateway over the 100,000 iterations (48,032 drops per iteration). The weighted EIRP distribution were used from Table 5-10.

The distributions of pointing directions for the MSS gateway earth station antenna are generated using a separate simulation of the MSS constellation per MSS Gateway characteristics (Table 5.8) and system parameters in the table below.

Table 5-11 – MSS Constellation System Parameters

MSS Constellation Parameter	Value
Number of LEO Satellites	24 (3 satellites /plane x 8 orbital planes)
Orbital Plane Inclination	52°
Satellite Altitude	1,409.78 km

The figure below, a screen shot taken from the IFT's Map of Non-Geostationary Satellites with Footprint in Mexico for the sole MSS satellite constellation with a downlink between 6875-7075 MHz, provides a snapshot of the satellites in view of the MSS gateway at a random moment in time. Over time, various satellites in the constellation with pass within view over the MSS gateway at different elevation angles. The screen shot is meant to be illustrative of the MSS constellation modeling and overall methodological approach.

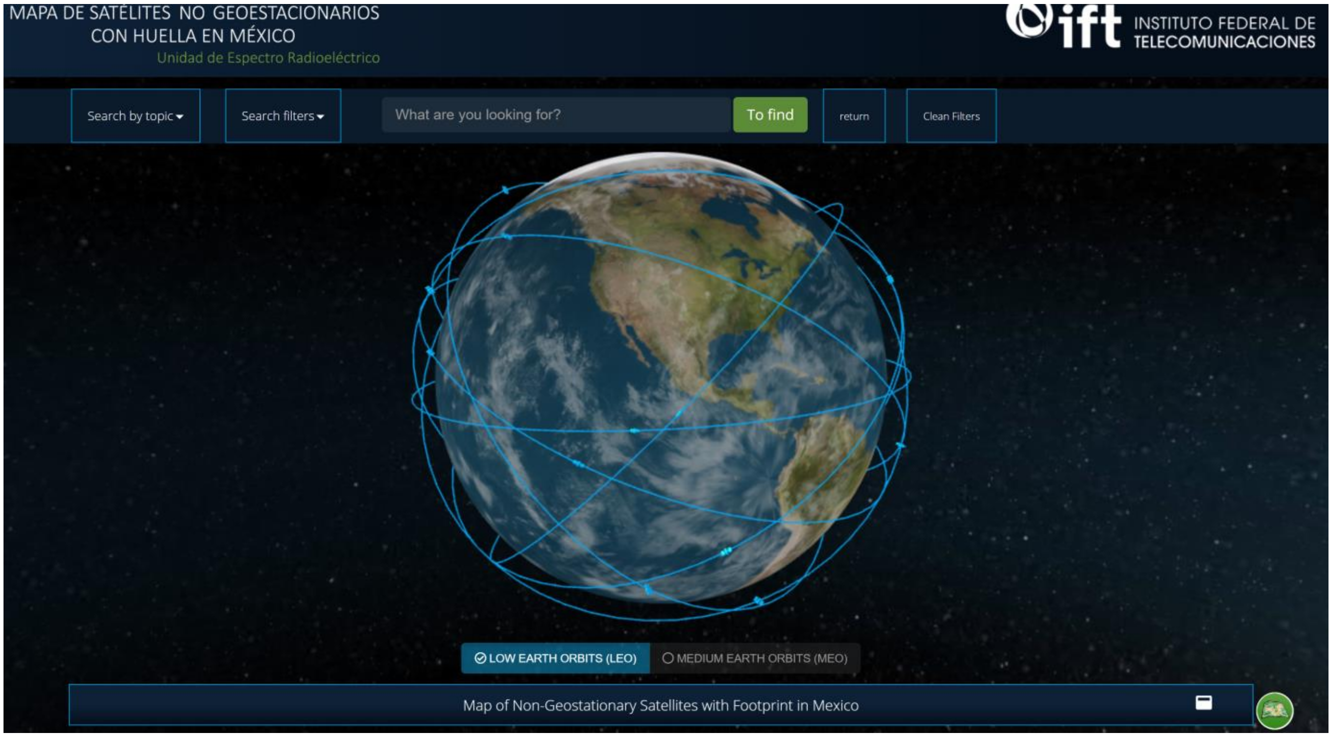


Figure 5-28 – Screenshot of IFT Map of Non-Geostationary Satellites with Footprint in Mexico with a 6875-7075 MHz Downlink[50]

The movement of the MSS constellation is plotted over time as viewed from the MSS gateway earth station antenna. In each of the 20,000 iterations, the pointing direction of the earth station antenna is chosen randomly from one of the 50,000 that is generated by simulating the MSS constellation's movement. At each snapshot in time, the earth station antenna pointing direction is chosen by picking randomly, one of the satellites that is above the radio horizon. The minimum elevation angle is assumed to be 10 degrees.

The CDF of the earth station antenna elevation is plotted below. Note that about two-thirds of the earth station elevation angles are below 30 degrees, 90 percent of the satellites are below 50 degrees, and there are no earth station elevation angles above 80 degrees (no satellites directly overhead).

[50] http://mapasatelital.ift.org.mx/nogeoestacionarios#

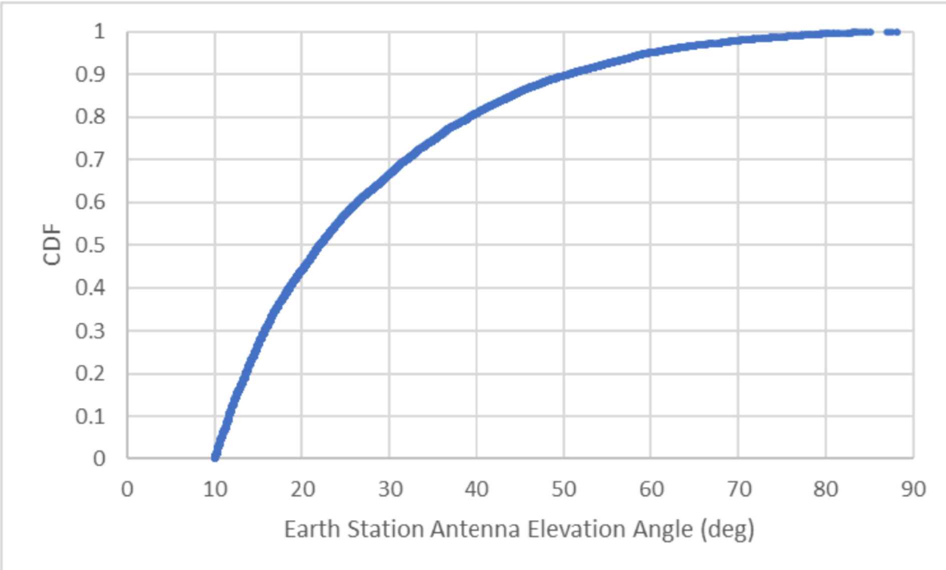


Figure 5-29 – CDF of Earth Station Antenna Elevation Angles

5.3.4 MSS Simulation Results

The cumulative probabilities of I/N were calculated for each of the three RLAN classes and for the total number of RLAN devices and are presented in Figure 5-30 below.

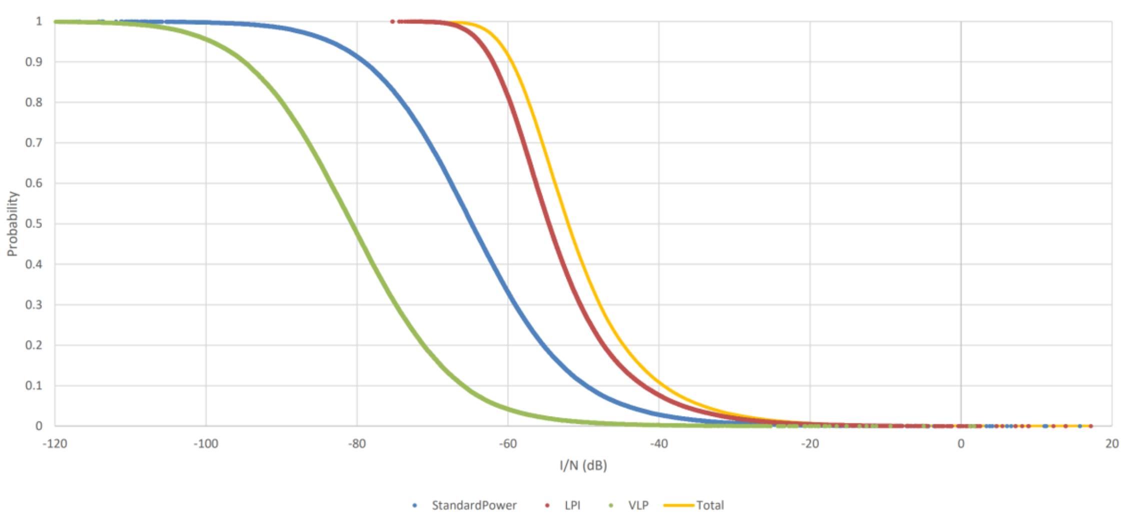


Figure 5-30 – Cumulative Probabilities of I/N by RLAN Class and Total RLANs

Table 5-13 shows the cumulative probability of I/N exceeding values of -6 dB and -12.2 dB. Of the three RLAN classes, LPI devices have the highest I/N at a given probability because LPI devices make up nearly 80 percent of all RLAN units.

Table 5-12 – Cumulative Probabilities of I/N Exceeding -6 dB and -12.2 dB for Each RLAN Class and Total RLANs

I/N	Standard Power	LPI	VLP	Total
-6 dB	0.031%	0.049%	0.003%	0.083%
-12.2 dB	0.070%	0.146%	0.006%	0.223%

The probability of each RLAN class exceeding and I/N of -6 dB and and I/N of -12.2 dB is exceedingly small. This becomes even more evident when the 'tail' of I/N values in figure xx is expanded. For comparison purposes, in Table 5-5, the cumulative probability of RLANs exceeding -6 dB with respect to FS links is 0.209%.

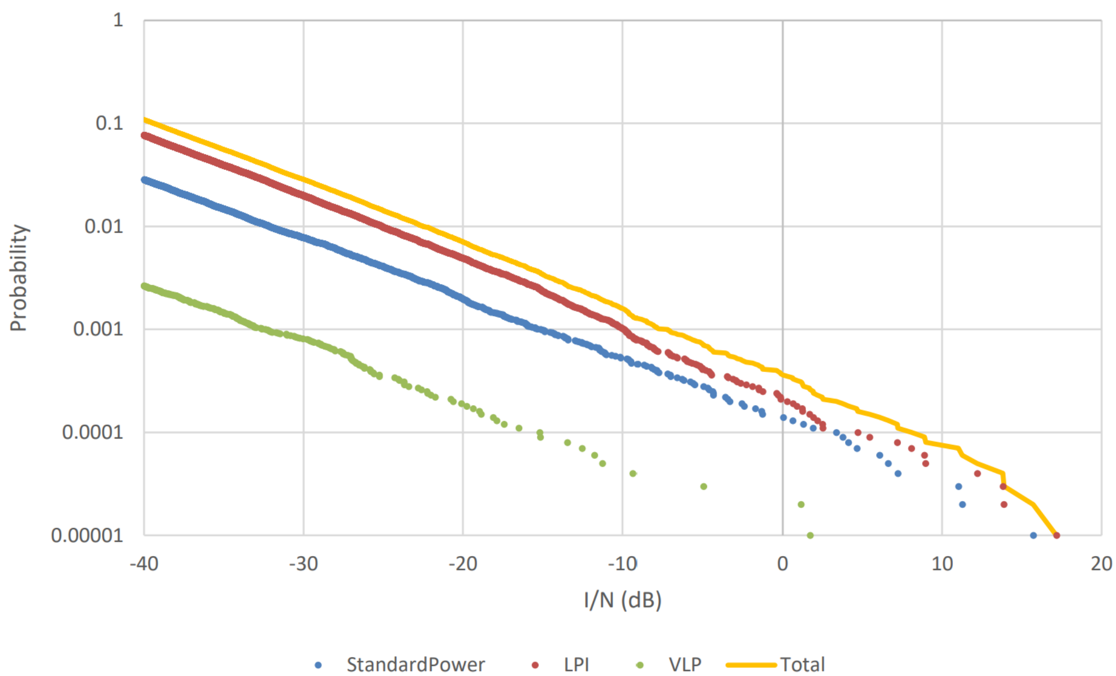


Figure 5-31 – Cumulative Probability I/N Greater Than -40 dB by RLAN Class and Total RLANs

The Monte Carlo study did not consider any mitigations. For example, if IFT were to allow Standard Power RLANs across the entire 6 GHz band under the condition that an Automated Frequency Coordination is required, co-channel operation would be prevented in proximity of the MSS gateway site. The MSS operator could create physical barriers (e.g., plant trees, build a berm) and work with its neighbors around the MSS gateway site to further reduce the already minimal probability of an exceedance of the IPC.

5.3.5 MSS Gateway Coexistence Sharing Conclusions

The cumulative probabilities of I/N are presented for Standard Power, LPI, and VLP RLANs separately, considering MSS constellation and MSS gateway earth station coordinates and characteristics, assumptions regarding the characteristics and deployments of each RLAN class, and for random earth station pointing angles. The results of these studies clearly show that the risk of harmful interference to the future MSS gateway site's earth station antenna from Standard Power, LPI, and VLP RLAN devices is extremely low.

This result is consistent with the conclusion reached by the US FCC reached with respect to the domestic MSS gateway sites operated by Globalstar, Inc.

In its 6 GHz Report and Order the US FCC said, "Globalstar which operates earth stations receiving in the U-NII-8 band, claims that allowing indoor use of the U-NII-8 band would cause substantial harmful interference to its existing MSS feeder downlinks, and to any additional gateways that it may consider deploying in the future…With regard to earth station receivers, we disagree with Globalstar's analysis…[we] find that Globalstar's link budget analysis fails to fully consider all the probability factors that must align in order for interference to occur. We therefore find that the risk of harmful interference occurring to Globalstar's earth stations to be low."[51]

In conclusion, RLAN's in the three device classes -- Standard Power, LPI, and VLP -- do not cause harmful interference to the earth station antenna at the MSS gateway site.

[51] *See* 6 GHz Report & Order at ¶¶ 170-172.

6 GHz License Exempt:

Why the full 1200 MHz and why now?

Dynamic Spectrum Alliance

Broadcom Inc.

Cisco Systems Inc.

Apple Inc.

Microsoft Corporation

Facebook Inc.

Google LLC

Hewlett-Packard Enterprise

Intel Corporation

Qualcomm Incorporated

SUMMARY

Apple, Inc., Broadcom, Inc., Cisco Systems, Inc., Dynamic Spectrum Alliance, Facebook, Inc., Google LLC, Hewlett-Packard Enterprise, Intel Corporation, Microsoft Corporation, and Qualcomm Incorporated

August 2021

I. INTRODUCTION AND SUMMARY

In the almost two decades since countries globally implemented the World Radio Conference 2003 decision to open new spectrum in the 5 GHz range to license-exempt devices, there have been revolutionary changes in Wi-Fi technology, use cases, and demand. In a relatively short amount of time, Wi-Fi technology has moved from an amenity that helps make broadband connectivity more useful to an essential part of broadband delivery and an essential element in enabling businesses to get work done -driven in part by the rise to dominance of mobile devices and the expectation of near-ubiquitous wireless connectivity. In the home, Wi-Fi enables multiple users to simultaneously access the Internet, fuels video streaming to smart TVs, connects appliances to enable remote diagnostics and repair, and powers security systems, thermostats, sprinkler controllers, and more. At work, Wi-Fi supports access to enterprise networks for a range of applications, supports a variety of data communications, and connects all types of devices including robots, autonomous vehicles in warehouses, factory equipment, screens and whiteboards. At play, there is not a stadium being constructed today that does not have extensive Wi-Fi capability for fans, vendors, and administrative and team support. New uses for Wi-Fi have also appeared to address rural or disadvantaged populations, stemming from the need for low-cost infrastructure to help expand services to the unserved. By any measure, Wi-Fi is a massive success story that helps policymakers achieve critical objectives in broadband policy as well as in economic and social policy areas.

Wi-Fi® is...

- The most commonly used wireless communications technology
- The primary medium for global internet traffic
- A driver of $3.3 trillion USD in global economic value
- Growing, with more than 4 billion devices shipping annually and 16 billion devices in use*

**IDC*

Source: Wi-Fi Alliance

As companies and organizations that are device manufacturers, chipset vendors and applications providers that rely on license-exempt, licensed, and shared spectrum, we are excited to be part of a wireless industry that has done so much to advance global quality of life and economic growth. A key part of our job is to continue to innovate on the massive success already enabled by Wi-Fi. To do that, license-exempt spectrum access to the entire 5925-7125 MHz band is critical. This paper explains the technological reasons for this, and why recently introduced competing proposals are poor alternatives in comparison to opening the full 6 GHz band to license-exempt technology.

This White Paper consists of several sections that explain the essential need for availability of the full 1200 MHz from 5925-7125 MHz to support Wi-Fi and 3GPP's New Radio-Unlicensed.

- Opening the full 6 GHz band to license-exempt Radio Local Area Network (RLAN) technologies is the best public policy choice for regulators globally. **The full 1200 MHz is needed to supply new technologies with the spectrum necessary to deliver on current and emerging innovative use cases, now and in the future. With just 500 MHz**, license-exempt technologies will be unable to support advanced use cases or support even routine consumer and enterprise networking needs in a few short years.

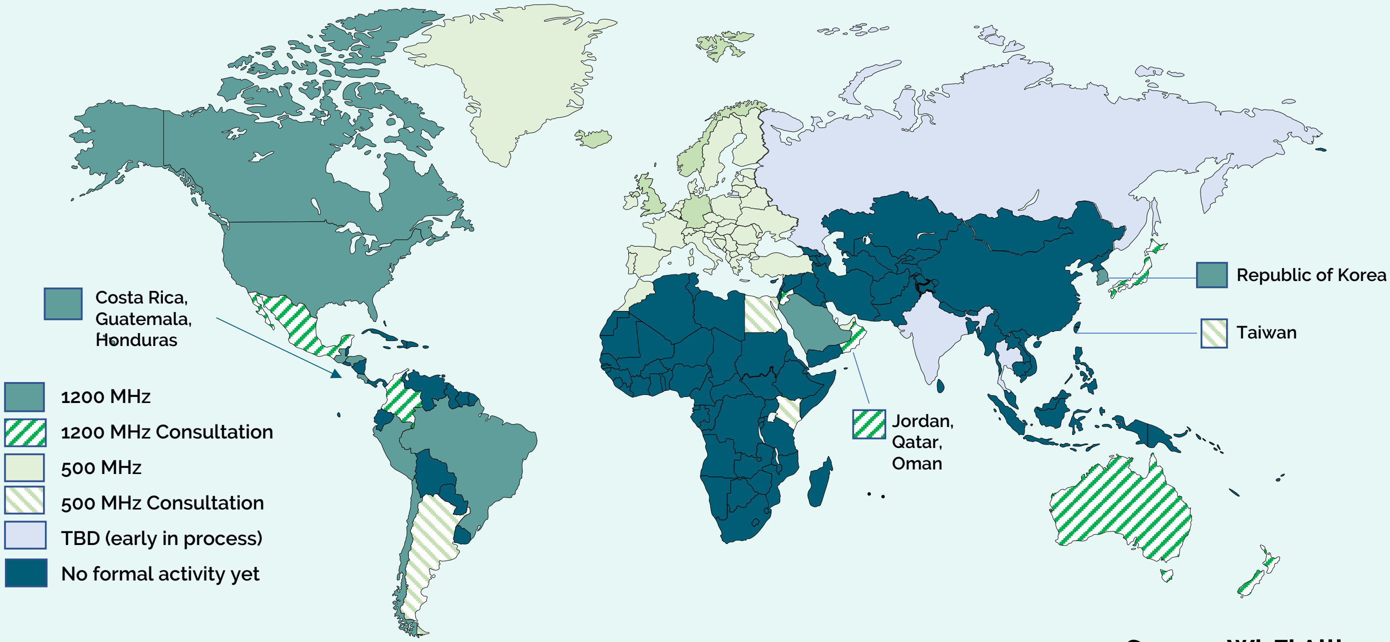
- The social and economic benefits of moving forward with allowing license-exempt usage throughout the full 6 GHz band are many. **Addressing the digital divide, improving rural connectivity, accelerating economic innovation, advancing energy efficiency through smart buildings and improving quality of service are just a few benefits** that regulators can look forward to when they open the full 6 GHz band to license-exempt use.

- **6 GHz Wi-Fi technology is ready now.** Standards are complete; interoperability certification is open, and equipment is moving into the market today. Benefits from spectrum use are available immediately.

- Failure to act brings with it large opportunity costs. **Any benefit of reserving a portion of the spectrum for a later decision on whether to allow IMT is entirely speculative and essentially nonexistent. No IMT specifications are in place nor is there any commercially available IMT equipment for this band.** Significant questions remain about technical feasibility of IMT use. One thing is certain if IMT to allowed in the upper portion of the 6 GHz band: Delay, which would result in immediate lost economic gains that would have accrued instead from opening the full 6 GHz band to license-exempt operations.

- License-exempt services in the 6 GHz band, operating **under appropriate regulatory conditions, enable incumbents to continue – and to grow – their operations in the band** while protecting them from harmful interference. Traditional wide-area IMT deployments in the band, however, would likely require that incumbents be cleared and/or relocated.

- The **best way to support 5G deployment in the 6 GHz band is to authorize license-exempt use throughout the entire 1200 MHz of the band, which supports mobile offload, 5G backhaul, and 5G NR-U operation.**



Source: Wi-Fi Alliance

This paper draws on the work of numerous regulatory agencies globally that have already designated the full 6 GHz band for use by license-exempt technologies. Since the United States Federal Communications Commission (FCC) released its decision in April 2020, and with the European examination of coexistence with incumbents drawing to a favorable close during the final months of 2020 and into early 2021, global momentum toward opening the 6 GHz band for license-exempt RLAN technology has been exploding. Importantly, in February, Brazil was one of the first Top 20 economies in Region 2 in 2021 to join the FCC in opening 5925-7125 MHz to license-exempt technologies, while Republic of Korea was the first in Region 3 in October 2020. Saudi Arabia boldly announced in March to its fellow Region 1 countries that it also would open the 5925-7125 MHz band to license-exempt use. Canada's Innovation, Science and Economic Development (ISED) soon followed in May, announcing that it is opening the full 5925-7125 MHz band to license-exempt use. Many countries have similarly been active in embracing license-exempt use of the full 6 GHz band. Peru, Costa Rica, Chile, Honduras, and Guatemala have all finalized changes to their Table of Allocations or to footnotes opening the full band as license exempt. Consultations or proceedings are now pending to open the full band in Japan, Mexico, Australia, Colombia, Qatar, Jordan, New Zealand, and Oman.

> As of today, regulators globally have reached a remarkable and swift consensus with 6 GHz regulatory decisions **covering nearly 54%** of the global GDP, and nearly **42% of GDP having opened** or proposed opening the full 6 GHz band to license-exempt use.

Countries that have opened the lower 500 MHz for license-exempt use also have made important contributions. The European Commission in June 2021 published its decision to open the band to license-exempt equipment after exhaustive study of the impact to fixed satellite uplink and to fixed microwave services. In both cases, the European process found that license-exempt equipment could operate in the band without causing harmful interference to incumbent users, provided that mitigation rules, such as limiting power levels, were applied. However, regulators –

and particularly those in countries outside Region 1 – should not assume that a 500 MHz license-exempt designation is sufficient or that Europe will in the future conclude that it is adequate.

In a little more than a year, the world has transformed to welcome a new generation of Wi-Fi into the 6 GHz band. As of today, regulators globally have reached a remarkable and swift consensus with 6 GHz regulatory decisions covering nearly 54% of the global GDP, and nearly 42% of GDP having opened or proposed opening the full 6 GHz band to license-exempt use. This swift action is happening in part because governments around the world have recognized the key role that robust broadband connectivity plays in the lives of their citizens, its importance to their economies, and in supporting national 5G deployments. The Covid-19 pandemic has brought these realities into sharp focus. Recently, the Wireless Broadband Alliance commented that Wi-Fi usage grew by 80% during the pandemic.

While those who were connected placed unprecedented demands on Wi-Fi networking capabilities, too many children, families, and rural businesses remain unconnected or inadequately connected. As we have witnessed globally, cellular technologies alone have not solved the connectivity problem for those outside the reach of mobile networks or for those who cannot afford mobile subscriptions. The lack of IMT identified spectrum is not the reason so many communities lack adequate connectivity. As policymakers prepare to consider the opportunity presented by allowing license-exempt use in the full 6 GHz band, putting this spectrum to work now to help people and economies should be a top priority.

II. OPENING THE FULL 6 GHZ BAND FOR LICENSE-EXEMPT TECHNOLOGIES IS IMPORTANT AND NECESSARY.

A. The technology imperative for 1200 MHz – current and future use cases driving demand, density and high bandwidth

Delivery of broadband access is a continuously-evolving challenge. Since broadband access was introduced to consumers in the 1990s, the use of broadband networks, the applications that run on these networks, the throughput capability of devices, and the density of device deployments continues in an unrelenting upward trajectory. Most people's access to their fixed broadband network is through Radio Local Area Network (RLAN) devices such as Wi-Fi routers; thus, RLAN access and quality equals broadband access and quality. For companies that develop equipment and networks using license-exempt spectrum, we must look ahead to future use cases, applications, and demands that are not yet in the market, and do our best to help create today the regulatory and technology environment that will address the exponentially increasing consumer and business requirements of tomorrow. Consumers, businesses, and governmental agencies around the world will be able to take full advantage of the technology evolution that industry has identified. Among other things, a wholly-new generation of RLAN technologies in the 6 GHz band will be enabled to address future networking needs for broadband access and beyond.

The last time a significant new designation of license-exempt spectrum for RLAN technology was made available was in the early 2000s, following the 2003 World Radio Conference. This activity opened new spectrum bands in the 5 GHz range, which were at that time optimal for earlier generations of RLAN technology, such as Wi-Fi 4, and later, Wi-Fi 5. In the almost two decades since that time, the equipment used for broadband networking, use cases, and applications, as well as engineering challenges to meet demand, have evolved considerably. In addition, the number of devices per user is proliferating. The capability of those devices – in processing power, screen resolution, streaming video support (now at 4k/8k HD), camera performance, and antenna

Device evolution requires improvements in network capability

iPhone 1 - 2,000-8,000 songs, up to 32 Gbps of memory, a 3.5 inch screen size with a resolution of 480 x 320.

iPhone 12 ProMax - 128,000 songs, up to 512 Gbps of memory, a 6.7 inch screen with a resolution of 2778 x 1284, and a more versatile camera capability, powered by a vastly more powerful processor.

functionality to name a few – has increased exponentially. Devices are deployed in increasingly dense residential or enterprise environments, and the broadband networks they connect to, whether wired or wireless, are also greatly improving in throughput and latency. But it is not simply the relentless improvements in devices that is increasing demand. New applications, such as consumer gaming or enterprise Advanced Manufacturing, demand low latency transmissions. An explosion in Augmented Reality/Virtual Reality/Mixed Reality (AR/VR/MR) technology is soon expected to impact everything from how we learn to how we work and play. While that capability exists today, connectivity must expand and improve for these services to be placed into routine use by citizens and businesses. As that occurs, devices will be produced at scale and will be differentiated by use case.

Augmented Reality - digital information layered over the real world

"Many of our enterprise clients, especially in construction and medical sectors, are embracing AR headset devices to provide hands-free enhanced vision for planning, design and patient care and training," says Sam Watts, immersive partnerships director at immersive learning and development studio Make Real.

AR is also beneficial for any industry that relies on planning and visualisation, this includes almost any type of design and conceptualisation needs. "We have a number of onsite AR tools, using Microsoft HoloLens, to visualise construction when the real world is just a cleared, muddy plot," Watts tells us.

--AR smartglasses in 2021: the devices, apps and new tech coming, Wareable.com posted 14 June 2021

Rural Internet access networks that use Wi-Fi (e.g., as part of a 60 GHz mesh or TV White Spaces Network) and Wi-Fi at the edge of satellite links and new low earth orbit satellite constellations are also evolving use cases that will give regulators new tools to address unserved or underserved populations. According to a recent review of the new low earth orbit constellations by the Asia Development Bank:

> *At the current public beta pricing level, Starlink's $99 monthly plan is not affordable for many consumers in developing Asia. However, variable pricing by market (at different purchasing price levels) could result in a more affordable service offering. Similarly, community Wi-Fi models could be deployed, such as those being implemented by Hughes/Express Wi-Fi in Indonesia and Latin America where an individual subscription supports time- or data-bound service to potentially hundreds of users consuming small data bundles (in the megabytes) through a publicly accessible Wi-Fi access point. Areas of limited subscriber base may be opportunities for direct or subsidized partnerships. -- ADB, Digital Connectivity and Low Earth Orbit Constellations, ADB Sustainable Development Working Paper Series, April 2021.*

For rural and unserved areas, it is clear that license-exempt technology is essential to enabling affordable services.

To further illustrate the dilemma faced as license-exempt technology producers look to the future, take an example where access points (APs) must be deployed in a dense configuration, such as a school, manufacturing plant, office, hospital, transportation hub, multi-tenant housing, or stadium. Each of these locations increasingly relies on license-exempt spectrum for broadband operations. As demand has increased, Wi-Fi APs have been deployed more densely, adding more capacity within the same overall network area. In general terms, the coverage area for an enterprise indoor AP has decreased from ~500-1000 meters2 in 2003, to ~250 meters2 by 2010, to as little as ~150 meters2 today. The practical limit of how densely APs can be deployed has been reached due to the resultant increase in radio frequency interference (both co-channel and adjacent channel interference). The only way to add capacity in these situations is through the use of multiple wider channels of

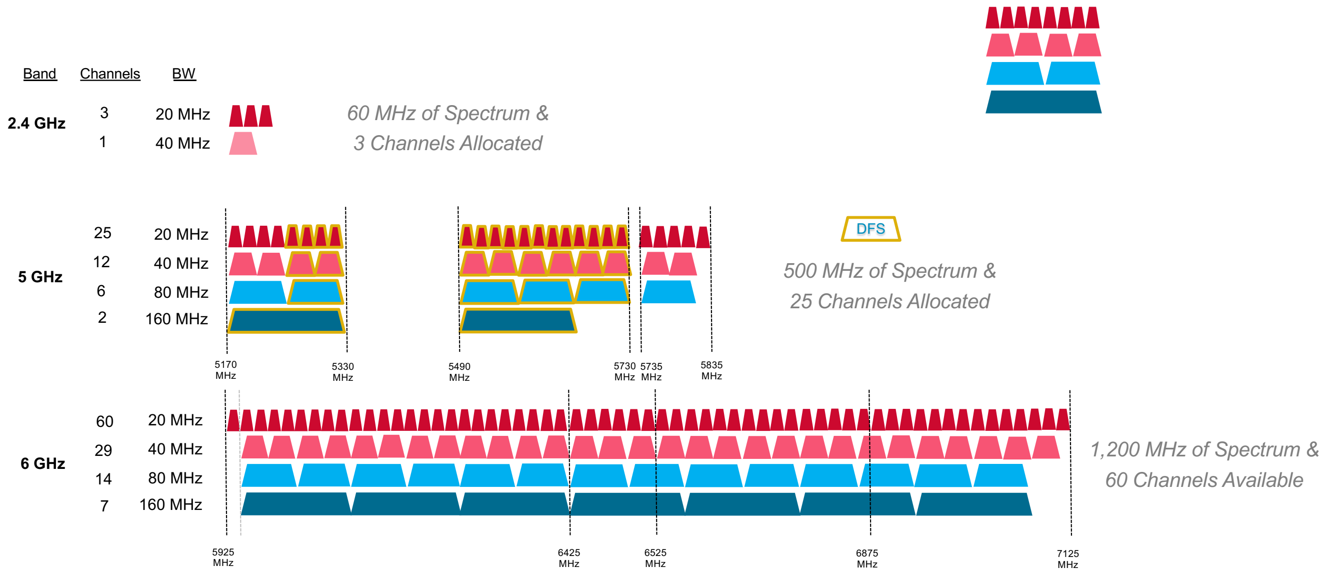
160 MHz and 320 MHz, which would be enabled by opening the full 1200 MHz of the 6 GHz band.

Forty (40) MHz channel sizes are increasingly insufficient to address the steep growth in the number of devices and higher bandwidth requirements per user. A typical two-stream client device can only achieve up to a 574 Mbps data rate when operating in a 40 MHz channel with Wi-Fi 6. When the channel width is increased to 80 MHz or 160 MHz, the data rate is increased to 1.2 Gbps and 2.4 Gbps respectively, fully enabling the "gigabit wireless" era. To retain the current quality of service for users in the future, 80 MHz-wide channels are required; to increase the quality of service, 160 MHz-wide (and larger) channels are required. With those wide channels, the radios can get on and off the air more quickly, delivering the high-bandwidth content users demand while maintaining the ability to share spectrum with other license-exempt transmitters. Lack of wider channels would create a detrimental impact on real-time video services, and high-bandwidth immersive services such as AR/VR/MR will be starved of sufficient capacity. There is no realistic possibility of delivering multiple 160 MHz wide channels on existing 2.4 GHz and 5 GHz spectrum allocations, which are too fragmented and which were allocated in an era of now-outmoded generations of RLAN technology.

To add to the engineering challenge, radios in the 2.4 GHz and 5 GHz bands today consist of multiple generations of equipment with a variety of less spectrally-efficient capabilities. This is a design necessity because networks must be able to communicate with older generations of radios. Therefore, technologies like Wi-Fi are always backward compatible with previous generations of Wi-Fi operating in the same frequencies. The additional requirement of interoperability between Wi-Fi generations and the burden of backward compatibility results in further reductions in efficiency and determinism that in turn further negatively impacts voice and video quality. Wi-Fi 6 in the 6 GHz band (known as Wi-Fi 6E) is not required to interoperate with any previous generation of 6 GHz Wi-Fi technology because no Wi-Fi has yet existed in the 6 GHz band. The 6 GHz band would, for the first time, eliminate outdated and less efficient radio access technology, permitting the far more spectrally-efficient Wi-Fi 6E (and above) to operate without the burden of legacy radio interoperability. This will dramatically improve the user experience and spectral efficiency, which will promote the adoption of advanced Wi-Fi technologies.

Considering all of these challenges, the license-exempt technology industry concluded that Wi-Fi 5 and earlier technology would soon be insufficient to deliver the required level of broadband and related capabilities in the near future. Industry's response was twofold – 1) to develop new, advanced technologies and 2) to find mid-band spectrum that could support the channel widths required for these new technologies.

First, we redesigned technology to enable a new approach to address dense networking, low latency, and higher-bandwidth needs. For example, deployment of OFDMA as part of Wi-Fi 6 fundamentally improves spectral efficiency, enabling an AP to communicate individual packet streams to multiple clients at the same time. In addition to adopting OFDMA, some of the most important innovations in the Wi-Fi 6 generation of technology are: (1) multi-user MIMO that allows more downlink data to be transferred at one time, enabling APs to concurrently handle more devices and support uplink as well; (2) 160 MHz channel utilization capability increases bandwidth to deliver greater performance with low latency; (3) Target Wake Time (TWT) significantly improves network efficiency and device battery life, in-



cluding for IoT devices; (4) 1024 QAM modulation increases throughput for emerging, bandwidth-intensive uses by encoding more data in the same amount of spectrum; (5) transmit beamforming enables higher data rates at a given range to increase network capacity; (6) addresses excessive management overhead relative to prior generations; (7) supports "Out of Band" discovery of networks, further reducing management overhead; and (8) strict scanning rules prevent unnecessary use of spectrum (e.g., only scans on a subset of the 6 GHz band channels). These innovations are a generational improvement in Wi-Fi technology, designed to take on the demands that future devices, applications, and use cases will present.

Second, to provide the spectrum needed to make these technologies practical, industry identified a large and contiguous allocation of spectrum, specifically 5925-7125 MHz, to support the wireless industry's need to migrate to multiple wide channels. Just as the cellular industry is migrating to 80 MHz and 100 MHz channels of mid-band spectrum per operator to support 5G services, the next generations of license-exempt technologies (e.g., Wi-Fi 7, and 5G NR-U) also utilize wider channel bandwidths. The additional 1.2 GHz of spectrum on which Wi-Fi 6E will run provides a roughly equivalent number of 80 MHz channels in 6 GHz band spectrum as there are 40 MHz channels in the 5 GHz band. For the first time, 80 MHz channel plans would be possible from a "best practices" perspective in dense deployments. Contiguous spectrum would also support seven 160 MHz wide channels and multiple 320 MHz wide channels, which are expected with the next generation of Wi-Fi now going through the IEEE standardization process (i.e., IEEE 802.11be). The Wi-Fi Alliance has named Wi-Fi 6 devices enabled for the 6 GHz band as "Wi-Fi 6E" devices. This is important not only because Wi-Fi is always backward compatible to earlier generations, but because Wi-Fi 6E devices are designed so that tri-band radios will be the norm, enabling legacy support in the 2.4 GHz and 5 GHz bands as well. With the full 6 GHz band, the RLAN industry can continue to play its important role in delivering broadband access, facilitating the IoT, and enriching experiences at work, home, and play.

In fact, Wi-Fi 7, which is currently being standardized in IEEE as 802.11be, relies on access to the greenfield spectrum of the 6 GHz band to deliver its greatest innovations, which could include numerous improvements to make Wi-Fi even more useful to users and applications that are currently in draft form or under discussion. While the need for 320 MHz-wide channels has been widely discussed, other innovations are also important. This new generation of technology will operate at 4096 QAM and permit "multi-link operation" that can use the 2.4 GHz, 5 GHz, and 6 GHz spectrum bands simultaneously. Once standards are complete, these improvements will enable lower latency, higher throughput, and more deterministic networking capability (e.g., higher reliability or QoS) relative to Wi-Fi 6E. These features provide a step function increase in terms of enabling Wi-Fi to address immersive services with demanding QoS requirements for a larger number and diversity of applications, devices, and use cases, in particular those of industrial IoT. In addition, these improvements scale throughput capability to future upgrades in access network capacity (e.g., 10G Fiber, DOCSIS 4.0, Fixed Wireless) allowing the RLAN wireless network to evolve with the broadband access connections. However, if there is insufficient spectrum available to make Wi-Fi 7 capabilities compelling to someone purchasing a new AP, Wi-Fi 7 may not see widespread use.

B. An allocation of 500 MHz in lieu of the full 5925-7125 MHz is not sufficient

If only 500 MHz of 6 GHz spectrum were made available, networks would effectively need to operate in a manner similar to the scenario playing out in the 5 GHz band today. Opening only 500 MHz of the 6 GHz band would require channel plans in dense deployments to continue relying on 20 MHz or 40 MHz bandwidths. In countries allowing access to just 500 MHz, users would not be able to take full advantage of the benefits of Wi-Fi 6 (and eventually Wi-Fi 7) in the 6 GHz band, lower service quality will be the norm, and congestion will fall on users of Wi-Fi in enterprises, schools, transportation hubs, and other public venues.

For consumers, congestion issues arise as the number of high-demand Wi-Fi enabled devices in a home continues to multiply. Countries such as Japan, Korea, and the United States are already at 12-14 devices per capita, and the continued integration of license-exempt technology into consumer durable goods promises that the number of devices in a home will continue to grow. Indeed, no analyst projects that the curve will flatten for the foreseeable future. That is because the advantages of connectivity continue to multiply: smart televisions that allow user choice in video streaming, connected security devices from video camera doorbells to whole home systems, and smart appliances that allow manufacturers to download new generations of software are examples of the types of new capabilities that were not in existence before the mid-2000s.

Nor are the coming challenges limited to consumers. Hospitals increasingly rely on video and robotics. Schools at all levels require connectivity to each student's laptop or tablet, and they are seeing increased demands on their wireless networks from security systems to remote learning. Whole industries are transforming how they operate by deeply integrating wireless technologies into their business operations. Cisco has projected that globally, machine-to-machine modules will account for 50% (14.7 billion) of all networked devices by

2023, compared to 33% (6.1 billion) in 2018.

With only a 500 MHz allocation of 6 GHz band spectrum, spectrum constraints will not, over time, support a good user experience particularly as applications evolve toward new immersive services. More devices would contend for airtime in the same frequencies as IoT and cloud-based analytics proliferate. Users would have a very mixed experience where applications might work in some locations, such as within certain portions of their home, and might not work well in other portions or in their businesses, public areas, and venues. Inconsistent bandwidth delivery has consequences well beyond consumer unhappiness – it inhibits innovation generally and may even stop developers from successfully creating and delivering new applications.

A "wait and see" approach, where 500 MHz is allocated now and the balance of the band is allocated sometime in the future, is a poor option. As discussed further below, there is an opportunity cost for countries that decide on a staggered approach to spectrum allocation compared to nations that decide to designate 1200 MHz from the outset. One main drawback is the opportunity cost of impaired use cases and inability to fully meet broadband needs, especially in dense enterprise and urban environments where more than three wideband channels (of 160 MHz and greater) are required. Countries that only designate 500 MHz of 6 GHz band spectrum will be unable to reliably support high-throughput and low-latency applications in all environments where those applications need to perform. When Wi-Fi 7 standards are completed in about three years, industry will implement channels up to 320 MHz wide. Countries that only designate 500 MHz of 6 GHz band spectrum for license-exempt use will not be able to fully experience the benefits of applications built to take advantage of that channel size. Opening all 1200 MHz of the 6 GHz band now enables countries to realize a stronger and more diverse license-exempt ecosystem, which will benefit the entire nation when 6 GHz applications and services are rapidly deployed.

Many types of equipment are expected to support the entire 1200 MHz of the 6 GHz band, as the United States, Brazil, Canada, Saudi Arabia, and the Republic of Korea are enabling the band for such operations, with many other countries expected to do so in 2021.

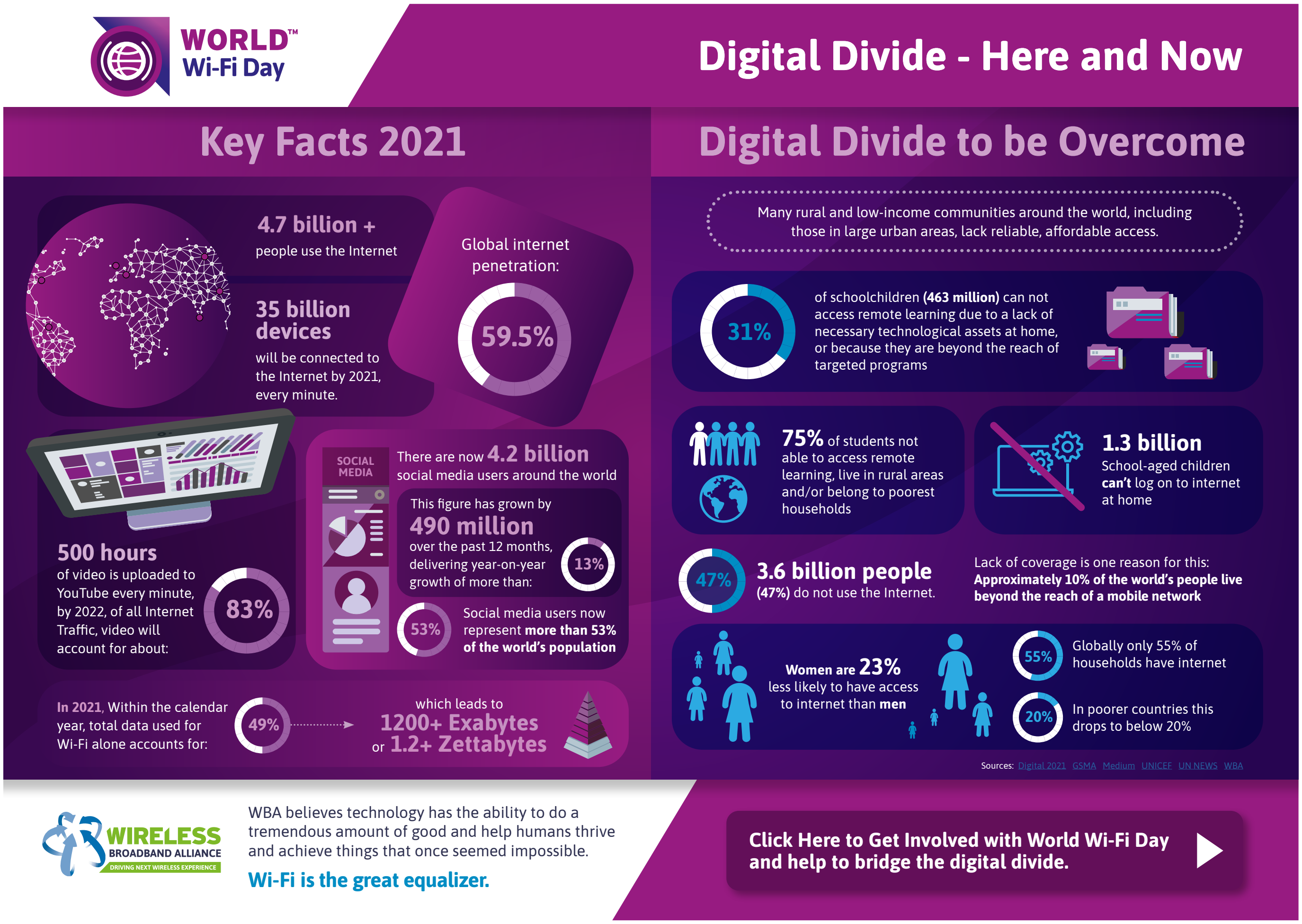
Many types of equipment are expected to support the entire 1200 MHz of the 6 GHz band, as the United States, Brazil, Canada, Saudi Arabia, and the Republic of Korea are enabling the band for such operations, with many other countries expected to do so in 2021. Due to the need to limit manufacturing and logistical complexity, most 6 GHz equipment will be designed to support the full 1200 MHz, with firmware settings used as necessary to limit operation to the lower 500 MHz. Without the full 1200 MHz available, consumers of 6 GHz equipment would not benefit from the higher throughput and lower latency, but would nevertheless pay for the more complete technology that they are unable to use.

Nor is there another spectrum band available that compares to the 6 GHz band and can deliver the same benefits. Most importantly, the 6 GHz band is adjacent to the 5 GHz band, enabling easier deployment of tri-band radios using 2.4 GHz, 5 GHz, and 6 GHz band frequencies. From a consumer perspective, 6 GHz band frequencies will deliver a consistent experience similar to that of the 5 GHz band assuming that reasonable power levels are adopted. From a regulatory perspective, license-exempt radio systems are highly complementary to incumbent systems and can coexist given the appropriate regulatory rules – and the incumbent systems are similar around the globe, which facilitates reasonably uniform sharing obligations on license-exempt devices as more countries open the 6 GHz band.

Another important consideration for countries initially authorizing only Low Power Indoor (LPI) and/or Very Low Power (VLP) operations in the 6 GHz band is preserving the opportunity for Standard Power (higher power indoor and outdoor) license-exempt operations. To date, regulators in the US, Canada, and in Europe have concluded that authorizing Standard Power devices can be done in a manner consistent with protecting incumbent fixed satellite services as well as fixed microwave through the combined efforts of power levels, projected number of outdoor devices, and geolocation database controls on the RLAN networks. Standard Power use cases are particularly important to a number of deployment types and settings, including manufacturing, logistics, agriculture, rural broadband, higher education, hospitality, healthcare, and municipal. Standard Power would operate in conjunction with an Automated Frequency Coordination (AFC) geolocation database capability, which is aware of incumbent user operations and can safely authorize Standard Power license-exempt use at a particular location while protecting the incumbents from harmful interference. Because of this requirement to avoid and protect incumbent services, the frequency ranges or channels that will be available at any particular location will often be only a subset of the overall spectrum that has been allocated for potential Standard Power use by the regulator. Importantly, the countries that have either already supported Standard Power or are actively studying it, including the United States, Canada, South Korea, and Saudi Arabia, have all moved to open the entirety of 5925-7125 MHz for license-exempt use in the Low Power and/or Very Low Power modes of operation. This allows for blocking or protecting certain frequencies or channels at particular locations, while still yielding a sufficient number of wide-bandwidth channels to support next-generation RLAN services. Opening the full 1200 MHz of the 6 GHz band to license-exempt use will provide the overall spectrum needed to support Standard Power under AFC control, whereas 500 MHz would be insufficient for Standard Power in the age of 80, 160, and 320 MHz channels.

C. Social and economic benefits flow from designating the full 6 GHz band to license-exempt use

Expanding spectrum availability for license-exempt technologies will help governments everywhere address improvements in broadband access for their populations and help close the digital divide. RLAN technologies such as Wi-Fi have an important role to play, particularly in offering low-cost mechanisms for multiple users in a household to connect to the Internet. License-exempt technologies are embedded in a wide array of client devices, from laptops to tablets and smartphones, that are part of a

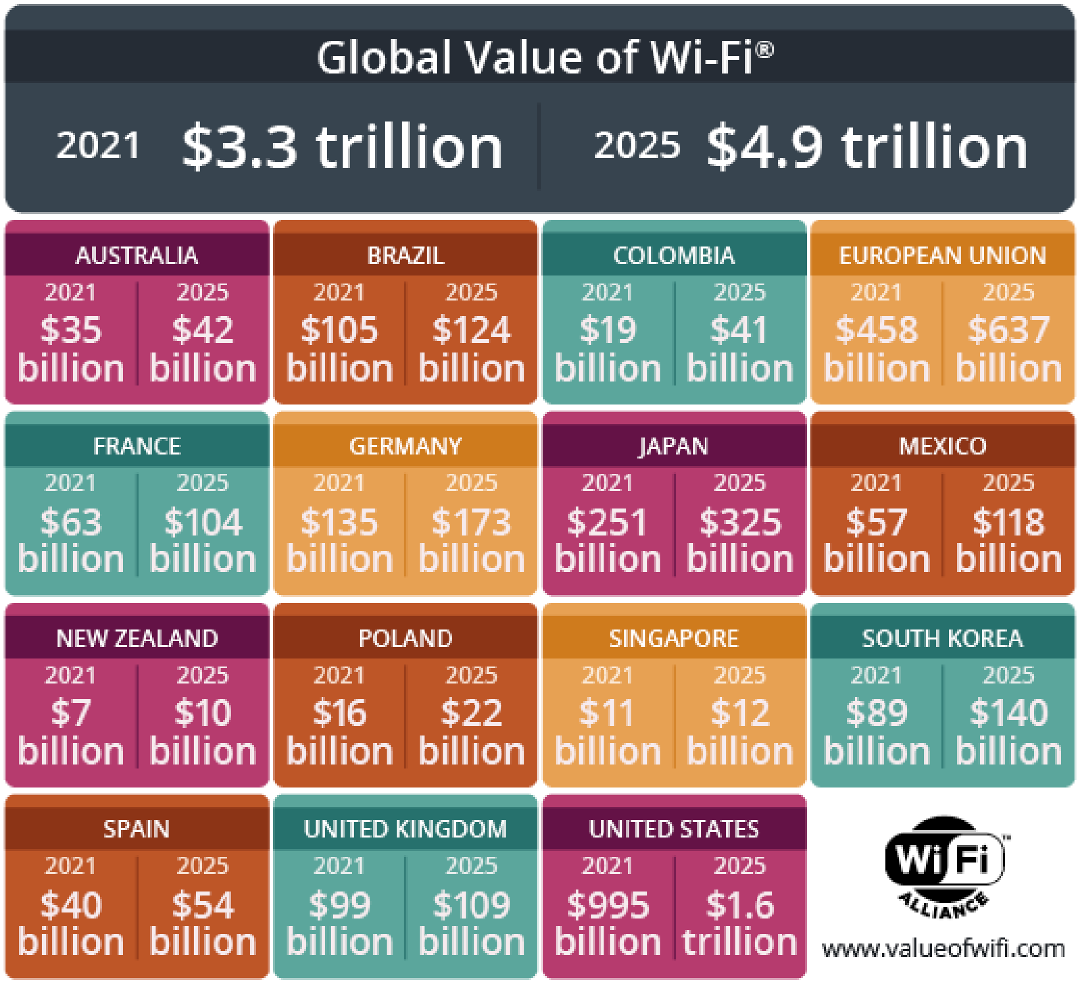


Source: Wireless Broadband Alliance

highly-competitive market that offers consumers a range of choices in device capability and price. Wi-Fi is also used to deliver rural broadband in areas where commercial wireline or wireless services have not been deployed. With backhaul spectrum capability similar to that in the 5 GHz band, TV White Spaces, or 60 GHz mesh, Internet service operators can offer broadband connectivity to households served by a Wi-Fi AP within the home. Similarly, satellite broadband connectivity also enables Internet access to a consumer inside the home, by using a Wi-Fi AP to reach the end device.

Ample spectrum for license-exempt use also gives market participants and governments new tools to reach unserved or underserved populations and can help provide low-cost broadband arrangements. The Digital Divide issue is so large and diverse that it is unlikely to be solved by any one technology. Regulators should advance all technologies that may be capable of addressing the Digital Divide, including low-cost options enabled by license-exempt spectrum technologies.

Allocating the entire 6 GHz band to license-exempt use provides important economic benefits. The Wi-Fi Alliance has conducted exhaustive studies with Telecom Advisory Services of the impact of Wi-Fi on global and national economies, concluding that globally, assuming regulators open the full 6 GHz band to Wi-Fi, the $3.3 trillion in Wi-Fi value to the world's economy in 2021 will rise to $4.9 trillion in 2025. The study examined ten sources of economic



Source: Wi-Fi Alliance

value, including: increased broadband coverage and broadband speeds; reduction of costs by telecommunications providers; deployment of IoT, AR/VR, municipal Wi-Fi, and free Wi-Fi hotspots; benefits of aligning with other major economies; increased capacity for cellular offload; and access to Wi-Fi equipment.

These projections reflect both global conditions now and in the coming years. In this regard, this economic forecast is similar to a technological forecast, but it differs in one important regard – it depends upon regulators to open the 6 GHz band to obtain the benefits that flow from robust license-exempt technologies. It also requires policymakers to think about the broadband future that is possible. This supports a larger point - the economic value of Wi-Fi will continue to rise as all forms of broadband connectivity continue to proliferate and increase in speed – whether fixed broadband as seen in the above chart or satellites such as the new low earth orbit satellite constellations or 4G/5G terrestrial mobile.

A growing group of leading regulators that have similarly concluded that the benefits of license-exempt technologies are important to their national interests. Among the key benefits cited are -

CITC 	"Importance of WLAN use in the Kingdom and **substantial amount of Wi-Fi traffic**, which was **exemplified during the COVID-19 lockdowns**, and the **emergence of a promising device ecosystem that can be taken advantage of starting from 2021**.
FCC 	"Most importantly, as explained in the Notice and in this Order, we believe that providing new opportunities for unlicensed operations across **the entire 6 GHz band can help address the critical need for providing additional spectrum resources for unlicensed operations**. Making the entire band available for these unlicensed operations enables use of wide swaths of spectrum, **including several 160-megahertz channels as well as 320-megahertz channels, which promotes more efficient and productive use of the spectrum**, and would also help create a larger ecosystem in the 5 GHz and 6 GHz bands for U-NII devices."
ISED 	"ISED continues to be of the view that releasing **the entire 1200 MHz of spectrum will immediately unleash the full potential of the 6 GHz RLAN technology**. Moreover, making the full 6 GHz band available for licence-exempt use as soon as possible **will maximize the social and economic benefits** that Canadians will derive from this spectrum. The increased demand for broadband Internet and, consequently, the spectrum required to support Wi-Fi enabled devices and applications for remote working and virtual learning, has been demonstrated over the past year with the COVID-19 pandemic. **Notably, current Wi-Fi capacity and speeds are the main constraint, even in homes with high-speed wireline connections, when a family unit is utilizing numerous Wi-Fi enabled devices. This discrepancy will only become more amplified as available wireline speeds increase**. The additional licence-exempt spectrum will provide the improvements needed in Wi-Fi throughput for homes and businesses and reduce congestion between neighbours living in close proximity. The additional spectrum will also support the ability for small wireless Internet service providers to provide **cost-effective enhanced broadband connectivity in rural and remote areas."**

Regulators in many economies have agreed with these views, with South Korea, Brazil, Chile, Costa Rica, Honduras, Guatemala, and Peru already acting to open the full band to license-exempt technologies. Regulators should put their countries on the same path to align with the growing consensus that the full 6 GHz band should be available for license-exempt use.

D. Wi-Fi technology, standards, and interoperability are all in place today, ready for regulatory action

Equipment is available to consumers and businesses as soon as license-exempt use is permitted in the 6 GHz band. RLAN operations can be introduced with mitigations to ensure that existing users are not adversely impacted, enabling countries to maximize benefits from the band without enduring the hardships of relocating incumbents. Enterprise, industrial, and governmental needs today and in the future also can be more easily met with the new generation of technologies designed to operate throughout the entire 6 GHz band.

Standards are ready

The IEEE has extended the latest Wi-Fi standard, 802.11ax (also known as "Wi-Fi 6") to include the 6 GHz band. The standard is complete and has been published. In addition to the IEEE standard, Europe's ETSI BRAN EN 303 687 has reached a "stable draft", providing further support for standards-based deployments. 3GPP-based licensed-exempt technologies are also in standards development, with New Radio-Unlicensed included in Release 16 covering the full 6 GHz band.

In addition, both the Wi-Fi Alliance (for IEEE 802.11) and WInnForum (for 5G NR-U) are engaged in projects to standardize the interfaces between Standard Power APs and AFCs. Standardization of the interface helps simplify AFC implementation because the two interfaces will be known and documented, creating built-in incentive for AFCs to utilize the standards. Standard Power APs can be manufactured and used with the confidence that the equipment will interface with any standards-compliant AFC.

Interoperability testing is ready

The Wi-Fi Alliance has named Wi-Fi 6 products capable of operating in the 6 GHz band as "Wi-Fi 6E" devices and released a certification plan for global interoperability as of January 2021. Interoperability testing has become the hallmark of technologies that use license-exempt spectrum, because it ensures that consumers can purchase devices with the confidence that the device will work with their router and with other devices. Multiple product vendors are already announcing Wi-Fi 6E devices that use super-wide 160 MHz channels and uncongested bandwidth in 6 GHz to deliver multigigabit, low latency Wi-Fi. Per the Wi-Fi Alliance, "Wi-Fi CERTIFIED™ provides a standards-based approach for product vendors to introduce secure and interoperable Wi-Fi 6E products throughout the world, helping to create a diverse device ecosystem." The first set of products already have been certified for interoperability.

6 GHz license-exempt equipment is entering the market

The United States FCC published its test requirements for the 6 GHz band, and the first devices have completed test review and approval. Then, FCC Chairman Ajit Pai marked the certification of the first device in December 2020 with the following statement:

> *We expect Wi-Fi 6E to be over two-and-a-half times faster than the current standard. This will offer better performance for American consumers at a time when homes and businesses are increasingly reliant on Wi-Fi. During the COVID-19 pandemic, we've all seen how Wi-Fi has enabled everything from work-at-home to telehealth to remote learning to streaming and gaming. Wi-Fi 6E will turbocharge each of these and more, and will also complement commercial 5G networks. Bottom line: The American consumer's wireless experience is about to be transformed for the better.*

With 6 GHz equipment testing rules now available, manufacturers can proceed to test equipment, and Telecommunications Certifications Bodies that receive the test reports prior to the certification application proceeding to the FCC laboratory can begin their review of manufacturer testing and begin independent testing. Dozens of successful 6 GHz equipment certifications have been completed, with significantly more expected this year.

Similarly, in Europe, with the ETSI standard reaching the stable stage, and with the first stage of the European process reaching completion, equipment is entering the European market as individual countries complete steps to adopt the European findings into national rules. And, the Republic of Korea's National Radio Research Institute has announced its revision of the test method for conformity assessment of radio equipment for the 6 GHz band. The Wi-Fi Alliance now projects that 340 million Wi-Fi 6 (802.11ax) devices will be sold in 2021 globally, with about 20% of them (or 68 million devices) 6 GHz-ready. Shipments of 6 GHz-capable Wi-Fi 6 devices are expected to ramp up very quickly in 2022 and beyond.

E. The opportunity cost of opening less than the full band to license-exempt use RLAN is great, with very limited near-term benefits attributable to an IMT designation

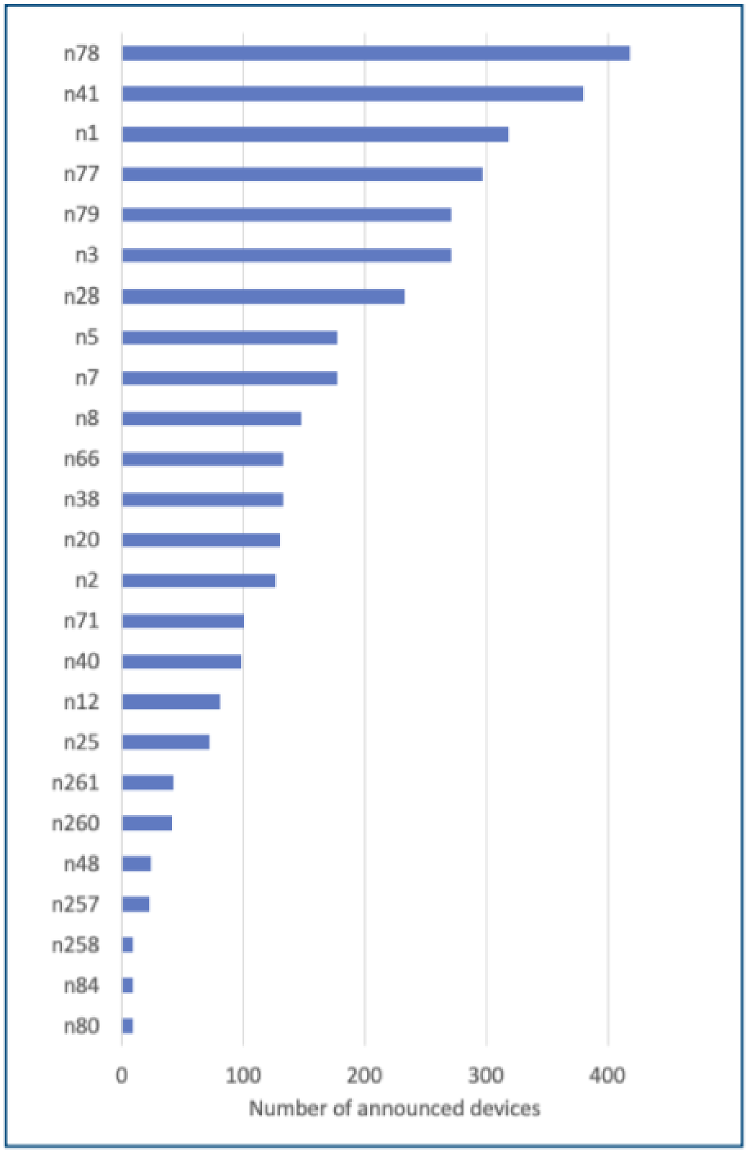
There is a real and significant opportunity cost to countries from not opening the full 6 GHz band for license-exempt use. As described in previous sections, the footprint of geographies that have already opened the full 6 GHz band ensure that there will be a global market for license-exempt equipment that uses the full 1200 MHz, and a continued drive toward global harmonization. The technology case for opening the 6 GHz band to license-exempt use is compelling; doing so generates important social and economic benefits. Countries that fail to act or delay action will fall increasingly behind in realizing the social and economic benefits of license-exempt use. Equipment is ready for the market, with standards and interoperability testing in place. Consumer, enterprise, industrial, and governmental needs today and in the future can be more easily met with the new generation of license-exempt technology designed to operate throughout the 6 GHz band.

Some parties may argue that the portion of the band above 6425 MHz should be reserved for possible IMT use, or that IMT technologies "require" 6 GHz band spectrum, but the arguments do not stand up to scrutiny. The IMT community's mid-band spectrum advocacy for many years has focused on spectrum in the 3 GHz range. For much of the last decade, the IMT community has advised governments globally that it is essential to make available 100 MHz per operator in this 3GHz range to support 5G needs, administrations did not identify 6 GHz as a pioneer band for 5G, and the IMT community did not even mention the 6 GHz band for their 5G needs. Most importantly from a cost-benefit analysis perspective, the IMT community did not advance the use of 6 GHz frequencies beyond ensuring that 5G New Radio – Unlicensed (i.e. 5G NR-U) be specified in its Release 16 for 5925-7125 MHz as Band n96. In 2019, GSMA, in a publication directed to operators about why they should care about 5G, said this:

> *"5G networks require access to spectrum in low, medium and high radio frequencies and in larger contiguous blocks than previous mobile generations require. Regulators that get as close as possible to assigning 100MHz per operator in 5G mid-bands (e.g. 3.5GHz) and 1GHz per operator in millimetre wave bands (e.g., 26GHz and 28GHz) will best support robust 5G services." GSMA, The 5G Guide: A Reference for Operators, April 2019.*

Notably, GSMA did not raise the 6 GHz band frequencies, and failed to list the 6 GHz band in its exhaustive appendix of "5G New Radio Spectrum Bands." The IMT community's actions over the last decade on the 6 GHz band, or rather its inaction, speak far louder than GSMA's recent hyperbolic press release describing the allocation of 6 GHz for license-exempt use a "clear threat to 5G". Regulators and policymakers globally have gone to great lengths to provide the 3 GHz mid-band spectrum that

Figure 5: Announced devices with known spectrum support, by broad category (data not available for all devices)



Source: GSMA April 2021

the cellular industry has long said was the critical enabler for 5G. The IMT industry should act to meet its promises for 5G with the spectrum that has been made available, not to claim that 6 GHz licensed spectrum is suddenly critical to enable 5G operations.

Today, the established path to mid-band licensed 5G is through the 3 GHz band (roughly 3300-4200 MHz globally). Most mid-band NR devices have been announced for the 3 GHz range (n77, n78) along with devices for the 2500 MHz band (n41) and 2100 MHz (n1). At 6 GHz, there is no New Radio specification for standard FDD or TDD 3GPP technology, although 5G NR-U has been specified for license-exempt use in the 6 GHz band. Because of this, there is neither infrastructure nor client device equipment that can support licensed New Radio in the 6 GHz band. In contrast, there are mature specifications for both LTE and 5G NR for the 3 GHz range, and infrastructure and client device manufacturers have implemented support in a wide variety of equipment already available in the market. Radios supporting 5G NR bands n77 and n78 in the 3 GHz range are the path to instant mid-band 5G as soon as 3 GHz band spectrum becomes available, just as there is a large and growing ecosystem of equipment that can instantly leverage designation of the full 6 GHz band for license-exempt use.

GSMA correctly recommends that policymakers and regulators "support harmonised mid-band 5G spectrum". With major markets, such as the U.S., Canada, South Korea, and Brazil, having allocated 5925-7125 MHz for license-exempt use, these frequencies will not be harmonized for licensed 5G. Instead regulators are making decisions to allocate the 6 GHz band in a way targeted toward easing the mid-band deficit of license-exempt spectrum around the world, keeping in mind that 5G NR-U can also use these frequencies.

Regulators around the globe agree that withholding the upper 700 MHz of the 6 GHz band for future consideration for IMT is inadvisable.

- In Canada, "ISED is of the view that delaying the release of the spectrum would not meet the policy objectives outlined in section 2, as it would hinder access to affordable broadband services for Canadians in rural and urban areas and would negatively impact the opportunities for innovation."

- In Saudi Arabia, the CITC noted that it favored 3 GHz band spectrum, not the 6 GHz band, for 5G mid-band needs, stating that its focus was on making 3 GHz band spectrum available for 5G. CITC noted "the substantial amount of licensed TDD mid band spectrum already being made available for IMT and 5G.... CITC believes that this bandwidth will be sufficient to cover the mid-band spectrum needs of IMT for the foreseeable future....The existing mid-bands for exclusive IMT use have robust ecosystems already as well as superior propagation characteristics. If mobile operators want to access the 6 GHz band, they can do so on a license-exempt basis using NR-U (which 3GPP has defined as band n96)."

- In Brazil, one commissioner explained that "IMT operators wanted us to give a part of this spectrum for licensed use, arguing that it was important for 5G. If we wanted to do that, we would have to wait until 2024 to start the discussion about that and maybe in 2027 we would have the deployment. Considering the moment that we are in right now, considering the pandemic, considering the need for connectivity for everyone for the recovery of the economy, considering all of that, we understood that we could not wait until 2024 or 2027 to start using this frequency band. That's so important. We decided to start using it right now, because right now we have the equipment, we have a Wi-Fi 6E ecosystem. If we waited more than six years to take this decision, these are six years that we lose all the innovation, all the revenues, all the development this frequency band may bring to our economies."

- In the United States, the FCC declined the "requests that we repurpose substantial portions of the 6 GHz band for new licensed services in place of new unlicensed operations and existing incumbents. Most importantly, as explained in the Notice and in this Order, we believe that providing new opportunities for unlicensed operations across the entire 6 GHz band can help address the critical need for providing additional spectrum resources for unlicensed operations.... Repurposing large portions of the 6 GHz band for new licensed services would diminish the benefits of such use to the American public."

Consistent with these observations, many jurisdictions have opened the full 6 GHz band to license-exempt use. It also is important to understand the status of and reasoning behind European action on the 6 GHz band. Europe's 2017 decision to evaluate the lower 500 MHz of spectrum was based on genuine but parochial concerns by a few countries, mostly those that were in the process of migrating narrowband fixed links from other bands into the upper portion of the 6 GHz band. To conserve regulatory administrative resources and to ensure that these narrowband fixed link transitions were completed properly, which then would allow for coexistence to be studied, these countries requested that the initial license-exempt study be restricted to 5925-6425 MHz. Other countries, however, proposed opening the full 6 GHz band to license-exempt use or suggested 5925-6725 MHz for the scope of the coexistence study. European regulators opted for a "lowest common denominator" approach, resulting in the initial study of 5925-6425 MHz. When the European Commission issued a final revision to the study mandate to reflect the compromise, it said:

> *Based on the results of the compatibility and coexistence studies covering the 5925-6425 MHz band to be carried out under this Mandate, the relevant harmonised technical conditions should enable the coexistence with other systems in this and adjacent frequency bands.*

Thus, once coexistence rules were established for the lower portion of the band, regulators have completed a relevant portion of the work that would be needed for a study of the upper portion of the band. Fully understanding the Mandate's meaning requires an understanding of the debate and ultimate resolution over the size of the band to be studied that preceded it – namely, an expectation that the upper portion of the band could be studied for license-exempt use in due course. In concluding its study of the lower 6 GHz band and approving LPI and VLP portable devices, the European Commission – and the European regulators that participated – did not decide that the upper portion should be used for IMT. Their mandate on that matter is silent.

In any event, the approach that European regulators used to define the boundaries of their study in 2017 has no bearing on the rest of the world. The rationale was internal-to-CEPT decision-making and should not serve as a limiting factor on how any other country studies the 6 GHz band. Nor should it cause other countries to fall short of adopting the best public policy outcomes possible.

> *In fact, no country has designated the 6425-7125 MHz spectrum for IMT. Therefore, there is an absence of consensus among the world's regulators – in contrast to the many countries embracing license-exempt use of the full 6 GHz band -- that any part of the 6 GHz band is necessary for 5G licensed mid-band spectrum. In light of this and the inactivity on the 6 GHz band among the IMT community discussed above, the benefits associated with reserving the upper 700 MHz of the 6 GHz band for possible future IMT use remain speculative.*

There is currently an ITU-R study question on coexistence between IMT and incumbent FS and FSS networks at 6425-7025 MHz (Region 1), as well as another on 7025-7125 MHz (globally). The study question is probably most noteworthy as another marker of the regulatory direction of the band, because Regions 2 and 3 specifically explicitly declined to join in on the Region 1 coexistence study at the WRC-19. Region 1 will be evaluating whether IMT could coexist with fixed satellite uplink, fixed microwave, and other services such as a mobile satellite downlink located in the 6425-7125 MHz band. In the 2017-2021 European examination of license-exempt coexistence, the European process concluded that LPI and VLP license-exempt devices could coexist with

Many types of equipment are expected to support the entire 1200 MHz of the 6 GHz band, as the United States, Brazil, Canada, Saudi Arabia, and the Republic of Korea are enabling the band for such operations, with many other countries expected to do so in 2021.

these same types of services at 5925-6425 MHz. While license-exempt devices can coexist with 6 GHz incumbent services previously studied, and therefore can likely coexist with many of the same services in the upper portion of the 6 GHz band, it is unlikely that IMT could coexist with these same services without significant modifications. The power levels and other mitigations included in the examination of the lower band coexistence between license-exempt and incumbent services are a strong indication of the kinds of limitations the IMT community would need to accept in the upper part of the band in order to coexist with incumbents.

The satellite community in Europe has recently and publicly articulated its view that "IMT use of the band 6425-7125 MHz would not be compatible with current & future satellite use of the band", although with certain conditions Wi-Fi (i.e., license exempt) use could be compatible – referencing the coexistence work done in the lower portion of the band. Regulators also have noted the serious and uncertain issues with respect to satellite uplink coexistence if IMT use is considered, with the FCC stating that such a plan presented "no certain or clear path" toward achieving IMT use. Similarly, the FCC said that microwave incumbents had concerns about the "reasonableness and practicality of relocation" if IMT was considered, as they did not see an opportunity for IMT and FS to coexist. Moreover, no regulatory proceeding on designating the 6 GHz band of which we are aware has included a clear expression of how IMT would propose to use the band and at what power levels, although additional detail may be forthcoming as part of the ITU-R study item. IMT networks are typically located outdoors to provide outdoor coverage. In the 6 GHz range it is expected that IMT networks would need additional EIRP to overcome the steeper building entry losses that occur with higher frequency ranges. This supports regulators' concerns about IMT's ability to coexist with incumbent services. Philip Marnick, Group Director of Spectrum for Ofcom UK, presenting at the Dynamic Spectrum Alliance Global Summit on 9 June 2021, shared a slide stating "IMT identification is being considered for region 1 at WRC-23. But coexistence between existing users and high power outdoor mobile is not possible – would require clearing incumbents".

The GSMA's new-found fervor for licensing 6 GHz and their calls for policymakers and regulators to "safeguard" the 6 GHz band for 5G in advance of WRC-23 do not address, or even acknowledge, the issue of what to do about the incumbent services present in the band. In sharp contrast, the license-exempt technology industry has been on the record since 2016 with the principle that their uses of 5925-7125 MHz would not only protect existing incumbent operations, but also provide for their continued growth.

Waiting for the outcome of WRC-23 is unnecessary – especially in ITU Regions 2 and 3 where 6425-7025 MHz is not even being considered, and only the top 100 MHz is to be studied for a With a high opportunity cost for failing to open the band to market-ready, license-exempt RLAN technologies, no obvious corresponding benefit to the public for reserving part of the band for yet-to-be-defined future IMT use, and serious and unresolved questions about the ability for IMT to coexist with 6 GHz incumbents (or, alternatively forcing the band to be cleared of incumbents) - opening the full 6 GHz band to license-exempt technologies immediately is the right policy decision.

F. With the right regulatory framework, FS and FSS incumbents can continue and grow their primary licensed uses

One important benefit of opening the full 6 GHz band to license-exempt technologies is that incumbent users are not required to be relocated, and in fact, can grow their network operations over time. Mitigations, such as lower power levels, indoor-only requirements, very low power levels for portable devices, and Automated Frequency Coordination (AFC) will ensure that licensed incumbent operations can continue. Moreover, as the FCC and ISED concluded, opening the band to license-exempt technologies will help drive development of new technologies that support shared use. According to Canada's ISED:

> *"ISED has performed detailed technical analysis on the coexistence of RLANs with existing users. Furthermore, ISED has reviewed and analyzed various technical studies submitted in other jurisdictions with similar incumbent users. ISED is of the view that, under the proposed licence-exempt approach, existing licensed users such as public safety agencies, major telecom operators for backhaul connectivity, satellite service providers and broadcasters will be able to continue to operate and grow in this band."*

Coexistence is essential as it avoids service disruptions and the regulatory uncertainty and delay associated with migrating users to new spectrum. Regulators should recognize license-exempt coexistence with incumbent operations as a significant benefit of opening the full 6 GHz band to license-exempt use.

G. Permitting license-exempt technologies throughout the full 6 GHz band is the best way to support both future growth and innovation in 5G through 5G offloading, backhaul, and NR-U

Regulators globally have also recognized the important and critical role that license-exempt technologies like Wi-Fi play in furthering the 5G market and cite this as a reason to allocate the entire 6 GHz band to license-exempt use. Many of our companies have interests in both licensed and license-exempt 5G technologies, and view both as necessary to deliver on future wireless demands. Spectrum allocations should be sufficient to support both. The two technologies interact in important ways. Designating

the full 6 GHz band for license-exempt technologies will play an important role in ensuring a strong 5G future for all.

First, license-exempt technologies support a substantial amount of mobile traffic offloads for indoor environments, saving operator capital expenses and conserving licensed mobile spectrum. Offloading mobile traffic to Wi-Fi networks generates enormous economic benefits that have been estimated in the tens of billions of dollars for operators' capital and operating expenses globally. When Canada opened the full 6 GHz band for license-exempt technologies, it stated that it expects offloading of mobile traffic to increase over time, which is consistent with more data being consumed inside homes or indoor business locations.

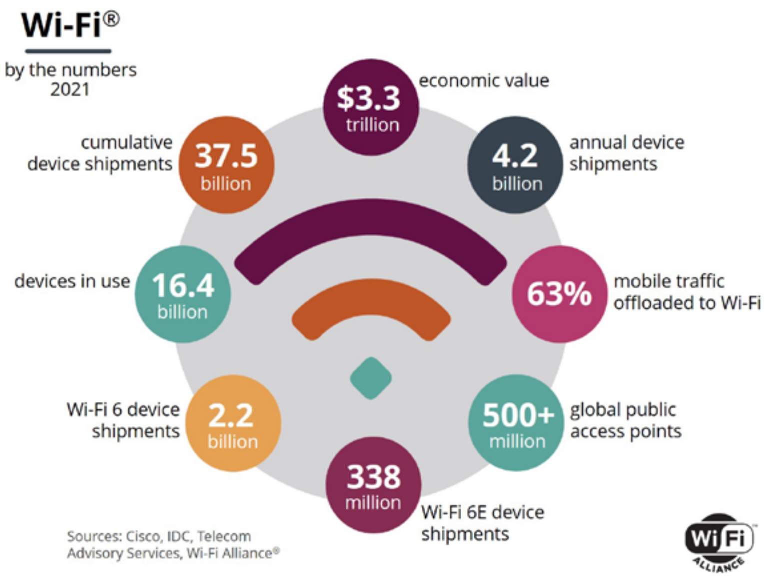
Second, incumbent microwave uses can remain in the 6 GHz band even after permitting license-exempt use, allowing for microwave links to remain available to support 5G networks. IMT interests have cited the 6 GHz band as potentially useful for backhaul, and operators today use the band to support backhaul for mobile operations. However, backhaul uses are licensed on a link basis and do not require large geographic footprints like IMT macrocells do. While fiber optic technology would be the expected backhaul technology of choice for 5G, depending on traffic volume, modern microwave links can be deployed as part of a 5G backhaul network. As 5G backhaul needs grow, more microwave links can be added to the band in support of operator networks; license-exempt technologies will not cause harmful interference to them. Third, 3GPP free use technology – 5G New Radio-Unlicensed – can be deployed by operators to extend their networks into license-exempt spectrum. Operators can use a 3GPP platform to take advantage of "free" spectrum while delivering 5G services to their subscribers. NR-U was standardized in 3GPP Release 16 for 5925-7125 MHz and is available today. Importantly, the NR-U and Wi-Fi industry have already been working on coexistence. Industry supports technology-neutral rules that would allow both technologies to operate in the 6 GHz band.

Via growth in offloading, backhaul, and NR-U, opening the 6 GHz band for license-exempt use provides strong support for the licensed 5G networks of tomorrow, while benefiting users of license-exempt technologies now and in the future. Maximization of the fulfilment of the broad and affordable mobile 5G vision requires Wi-Fi 6E as a component.

III. COUNTRIES SHOULD PROMPTLY ADOPT A LICENSE-EXEMPT MODEL FOR THE FULL 6 GHZ BAND

Opening the full 6 GHz band to license-exempt technologies is a critical step to foster innovation. Expeditious action by regulators will make spectrum available for new applications and services via successful and proven spectrum sharing techniques and facilitate increased availability of low-cost broadband access. With new 6 GHz products already entering the market, finalized rules will help to ensure that citizens and businesses can take full advantage of the latest, most advanced license-exempt technology available while keeping their countries positioned on the leading edge of innovation.

In the chart below, the Wi-Fi Alliance has summarized at-a-glance what the license-exempt industry delivers today, and industry is convinced more can be done. We have developed the technology. What is needed is access to the full 6 GHz band.



Source: Wi-Fi Alliance

Fixed and mobile broadband networks continue to get faster from the evolution in fiber and coaxial cable technologies, as well as from the transition from 4G to 5G (with 6G already on the horizon in standards bodies). At the same time, applications continue to become more bandwidth intensive as connected devices with increasing data demands continue to proliferate. The sustainability of this ecosystem is reliant on license-exempt technologies like Wi-Fi, which serve as significant delivery mechanisms for carrying massive amounts of data traffic for consumer and enterprise network customers. As broadband delivery networks, applications, and devices quickly gravitate toward increasing multi-gigabit connectivity, license-exempt technology must continue to be positioned to perform its essential functions.

Expeditious action by regulators will enable essential access to multiple wide 160 MHz and 320 MHz channels underlying the Wi-Fi 6 and Wi-Fi 7 standards and the vision of a more connected future. As countries take action, they will position themselves among the world's leading regulators that have opened the full 6 GHz band to license-exempt technologies. Regulators should promptly adopt rules opening the full 5925-7125 MHz band for license-exempt technologies, applications, and services.

Dynamic Spectrum Alliance

Broadcom Inc.

Cisco Systems Inc.

Apple Inc.

Microsoft Corporation

Facebook Inc.

Google LLC

Hewlett-Packard Enterprise

Intel Corporation

Qualcomm Incorporated

Wi-Fi and Broadband Data

June 2021

Jinous Shafiei, Ken Kerpez, John Cioffi, Pete Chow, and Djamel Bousaber;
ASSIA Inc.

Contact: Djamel Bousaber, dbousaber@assia-inc.com

http://www.assia-inc.com/

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2 INTRODUCTION

ASSIA collects many performance, status test, and diagnostics parameters from Wi-Fi customer premises equipment (CPE) and broadband fixed-line router equipment worldwide, and this report provides a view into that data. This report describes and presents a multitude of broadband and Wi-Fi parameters that show trends over time and relations between parameters. No single Wi-Fi parameter can show the entire network status, and so many parameters appear here. This document further describes the process for creating this data, and for each data category a description of what the data represents.

Data appears separately for North America and Europe. This report presents data from North America and for Europe for a nine-month period from May 28, 2020, to February 28, 2021, where data for North America includes the USA and Canada, but does not include Mexico. Linear regression was performed on daily data, finding the minimum mean squared error (MMSE) straight-line fit to the data, and the resulting trends appear in Table 1 and Table 2 below:

Table 1. Annualized Percent Change in Wi-Fi Data.

	2.4 GHz	**5 GHz**
North America		
Wi-Fi traffic, downstream	4.4%	30.2%
Wi-Fi traffic, upstream	5.5%	22.5%
Wi-Fi interference*	7.1%	18.3%
Wi-Fi congestion in busy hour	-3.6%	760.9%
Wi-Fi latency	13.4%	21.7%
Wi-Fi throughput / transmit rate	-7.3%	-18.8%
Europe		
Wi-Fi traffic, downstream	42.0%	42.0%
Wi-Fi traffic, upstream	14.4%	21.8%
Wi-Fi interference	3.7%	5.4%
Wi-Fi congestion in busy hour	64.0%	28.6%
Wi-Fi latency**	29.9%	5.7%
Wi-Fi throughput / transmit rate	-8.7%	-8.4%

* North American Wi-Fi interference is the trend up until the discontinuity on November 27.

** Europe Wi-Fi latency is the trend until November 27

The *increases* in Wi-Fi traffic, interference, and latency indicate a scarcity of available spectrum.

Wi-Fi throughput / transmit rate is the throughput available to an individual AP divided by the maximum transmit rate on that channel. The *decreases* in throughput / transmit rate also indicate a scarcity of available spectrum.

Table 2. Annualized Percent Change in Broadband Data.

Broadband	Downstream	Upstream
North America		
Broadband traffic	31.6%	40.6%
Broadband throughput	49.8%	65.8%
Europe		
Broadband traffic	39.0%	23.5%
Broadband throughput	-2.2%	116.7%

2.1 ANONYMIZED HISTOGRAM DATA

Per-connection datum x_A measures a line analytic (like Broadband or Wi-Fi traffic) for internet service provider (ISP) A on a particular continent (e.g., North America, Europe) for a particular parameter *x.* A histogram vector H_{xA} of values for x_A represents an array of estimates of the probability density function corresponding to an array of histogram bin start and stop values. Histogram vectors H_{xA} are constructed separately for each day or hour over the connections to each subscriber (line) in ISP *A*'s network. Each histogram-vector element equals the number of lines that have the parameter *x* between the histogram bin start and stop values, divided by the total number of lines, where each line represents a single user's Wi-Fi network.

Histograms are merged across multiple ISPs for each continent, and these merged histograms are provided to DSA. ASSIA uses a confidential continental weighting among ISP's *A, B, C, ...* , which is $w_A, w_B, w_C, \ldots$ where $w_A + w_B + w_C + \ldots = 1$. The list of ISPs and associated weighting on a particular continent cannot be disclosed. An overall histogram for the set of ISPs on each continent $C_i = \{A, B, C, \ldots\}$ is available to DSA as

$$H_x^i = w_A H_{xA} + w_B H_{xB} + w_C H_{xC} + \cdots = \sum_{j \in C_i} w_j H_{xj}$$

This histogram permits calculation of quantities such as average values, means, medians, quartiles, 90% worst-case for the continent. The weighted final histogram anonymizes fully the original per-line and ISP-identity data so that this data derived across multiple ISPs no longer belongs to any of them and is anonymized.

2.2 HISTOGRAM EXAMPLE

Here is an example to illustrate the meaning of the histogram plots. Figure 1 considers the daily Wi-Fi downlink traffic for 5 GHz with a simplified plot. This plot shows a histogram. The x-axis shows traffic in GigaBytes (GBytes) per day. Each histogram bin is 20 GBytes wide, so the first bin is from 0 to 20 GBytes, the second bin is from 20 to 40 GBytes, etc. There are five histogram bins, spanning from 1 to 100 GBytes in total. Each bin is labeled on the x-axis by the value in the center of the bin; for example, the first bin from 0 to 20 GBytes is labeled as 10. The y-axis shows the percent of all the lines which have data within each bin. For example, 87% of all the lines have data in the first bin; meaning that 87% of all lines have downstream Wi-Fi traffic between 0 and 20 GBytes/day.

The second bin shows that 9% of the lines have traffic between 20 and 40 GBytes per day. Here a "line" represents a single broadband subscriber.

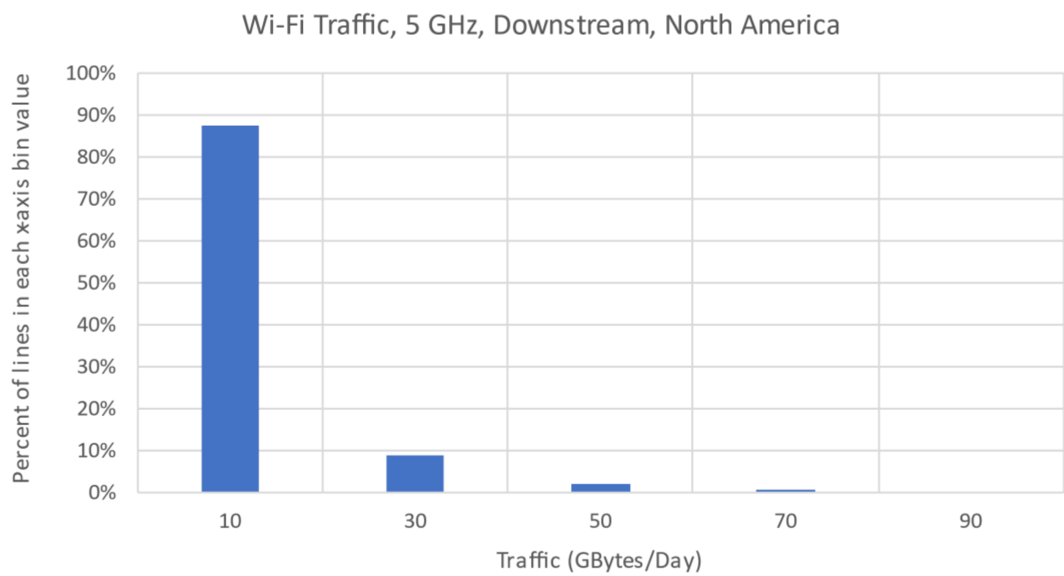

Figure 1. North America, Wi-Fi traffic 5 GHz Downstream 5 bins.

Next, Figure 2 shows the same data as Figure 1 above, but with 50 bins instead of five. Now each bin spans 2 GBytes instead of 20.

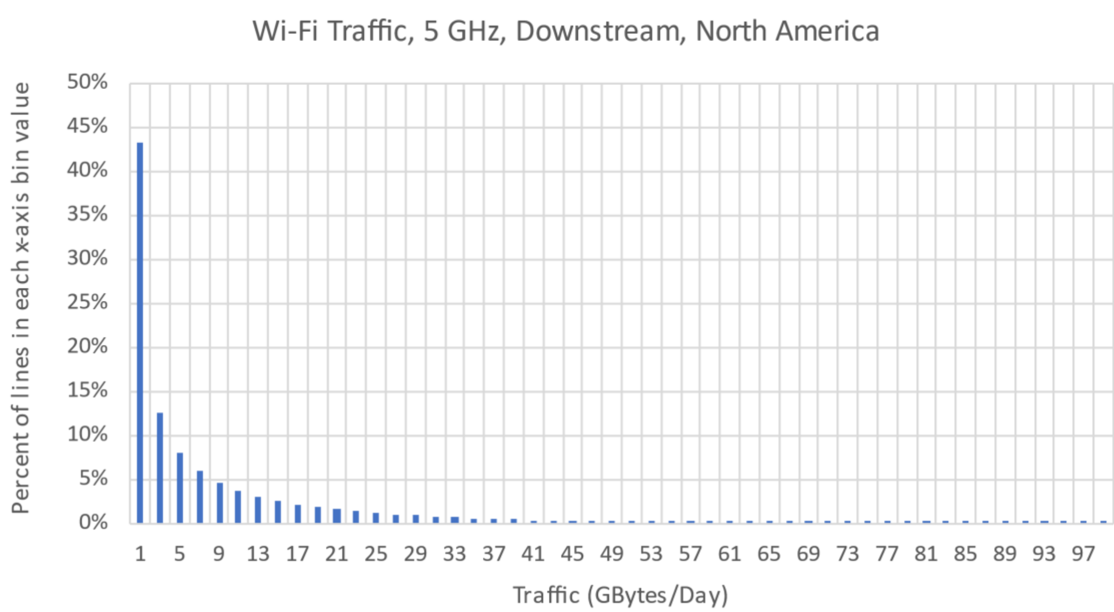

Figure 2. North America, Wi-Fi traffic 5 GHz Downstream, 50 Bins.

The histograms here generally have 100 bins. This is a large number, for accuracy, but it can be down-sampled for plotting. Plots presented further in this report simply show curves across the top of all bins instead of all the columns as shown above; this is easier to read and allows multiple curves on a single figure. Data was recorded every day, and the histograms presented here generally show the average across all the recorded days.

Data can equivalently be plotted as a Cumulative Distribution Function (CDF), as shown in Figure 3. At a given x-axis value in the CDF plot, the y-axis shows the total percent of lines at or below that x-axis value. The y-axis of the CDF also equals the sum of all histogram bins at or below that x-axis value.

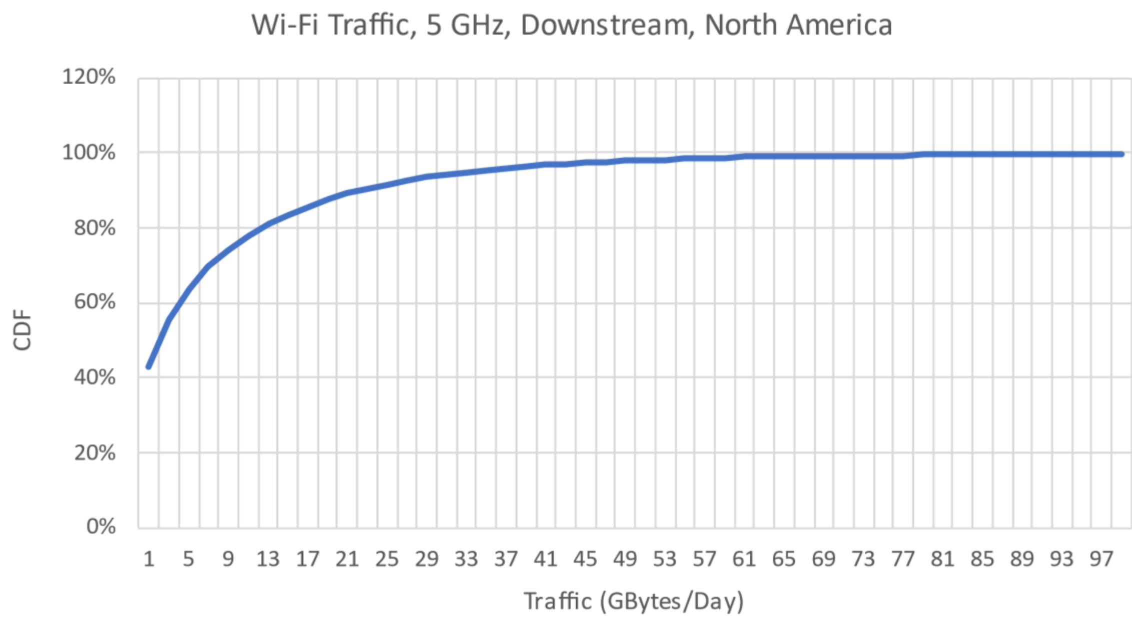

Figure 3. North America, Wi-Fi traffic 5 GHz, Downstream, Cumulative Distribution Function (CDF)

Histograms are recorded for each day and in some cases for each hour each day. Currently the plots run across nine months; over time more data will accumulate across a longer time-scale. Some figures show visible discontinuities, which may be due to the particular equipment reporting the parameter values, or due to the quantization of the originally recorded data.

The reader may ask why we recorded histograms instead of a simpler parameter such as the average or median. The answer is simple: the histograms contain a wealth of data. Data is accumulated from well over a million samples for each continent; this allows us to accurately represent the underlying probability density function. The histogram can thus be used to provide many statistics: CDF, mean, median, standard deviation, higher-order moments, correlations between times or between different parameters, etc. Some plots of these are shown in later sections.

3 WI-FI DATA PARAMETERS AND PLOTS

Histograms are recorded both for North America and for Europe, for the Wi-Fi parameters shown in Table 3. The histograms have data for a nine-month period from May 28, 2020, to February 28, 2021. Parameters with hourly data contain data for each of the 24 hours in each of these days. All Wi-Fi data is collected and split into 2.4 GHz and 5 GHz collections. The data is collected over millions of lines.

Table 3. Wi-Fi Parameters

Wi-Fi Throughput (speed)	Daily, 2.4 and 5 GHz bands
Wi-Fi Transmit Rate	Daily, 2.4 and 5 GHz bands
Wi-Fi Throughput / transmit rate	Daily, 2.4 and 5 GHz bands
Wi-Fi Congestion	Daily and max hour, 2.4 and 5 GHz bands
Wi-Fi Interference	Daily and hourly, 2.4 and 5 GHz bands
Wi-Fi Traffic	Daily and hourly, upstream and downstream, 2.4 and 5 GHz bands
Wi-Fi Latency	Daily, 2.4 and 5 GHz bands

3.1 WI-FI THROUGHPUT

Wi-Fi throughput is measured periodically, as often as every 15 minutes, by an active probe "speed test" between the Access Point (AP) to each station. The agent on the Wi-Fi Access Point (AP) measures Wi-Fi throughput using active probing to estimate the capacity of a Wi-Fi link by stimulating the network with injected traffic and collecting performance statistics.

The throughput reported here is an aggregate interface measurement over all stations measured. Data is collected at intervals throughout a day, and the median throughput of all measurements is plotted or the particular geographic region over all service provider links.

Wi-Fi throughput is the measured achievable data rate with no congestion but including interference from other Wi-Fi BSSs. Throughput is only measured when the link congestion (see Section 3.3 for congestion definition) is zero so that no station associated to the same BSS is producing traffic. The throughput includes the effects of interference.

The histograms of Wi-Fi throughput with 100 bins have:

- For 2.4 GHz, 2 Megabits per second (Mbps) span per bin with a maximum value of 200 Mbps.
- For 5 GHz, 10 Mbps span per bin with a maximum value of 1000 Mbps.

3.1.1 North America Throughput

Figure 4. presents the CDF of throughput in North America, averaged across all days for the recorded time period. It shows separate curves for 5 GHz and 2.4 GHz bands.

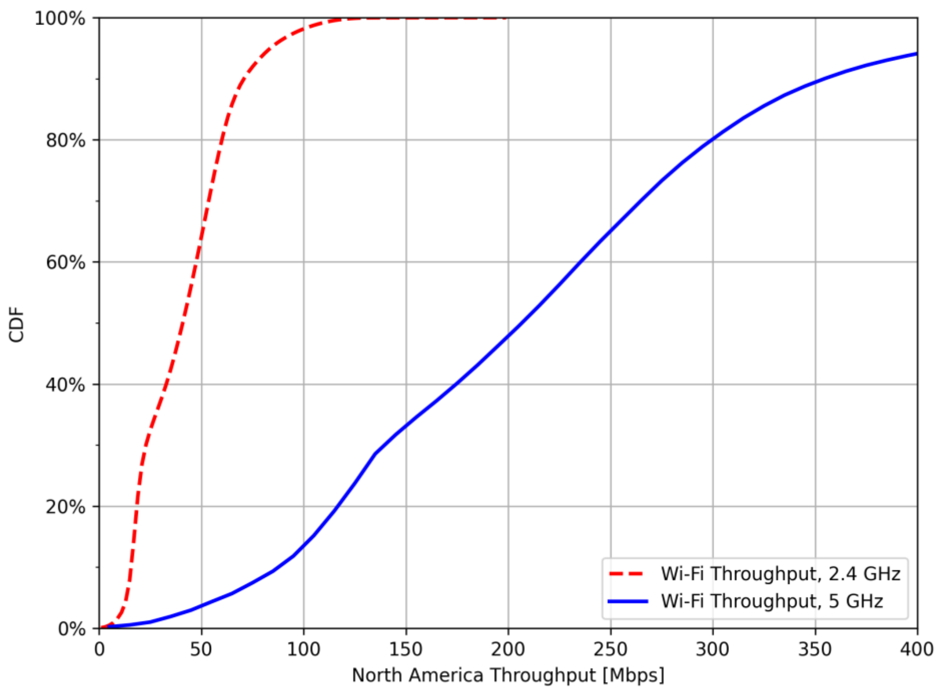

Figure 4. North America, Wi-Fi Throughput CDF for 5 GHz and 2.4 GHz.

3.1.2 Europe Throughput

Figure 5 presents the CDF of throughput in Europe for the recorded time period. It shows separate curves for 5 GHz and 2.4 GHz bands .

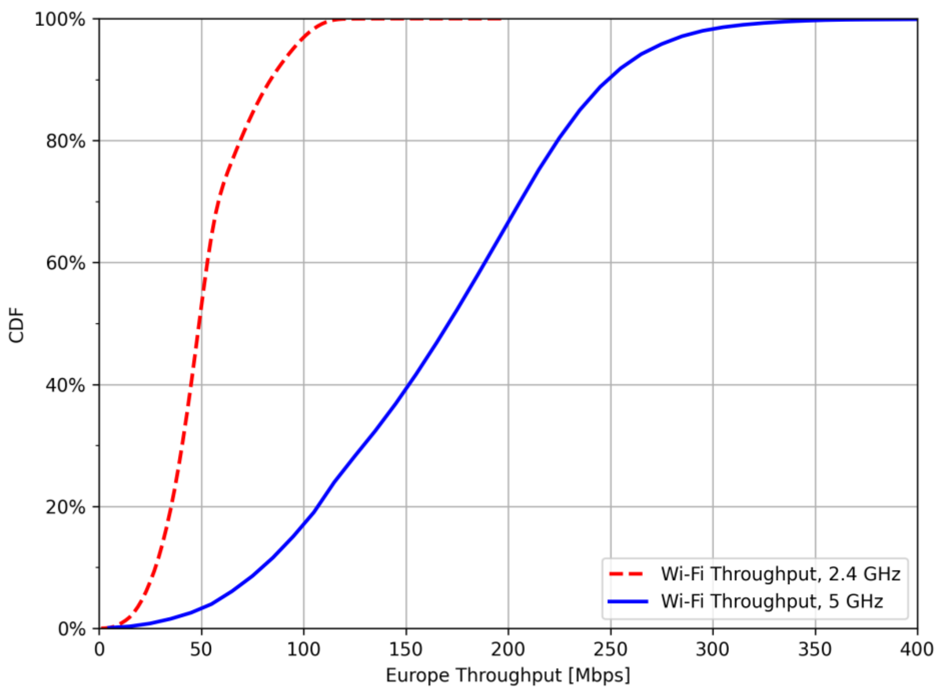

Figure 5. Europe, Wi-Fi Throughput CDF for 5 GHz and 2.4 GHz.

Figure 6 shows the daily trend in the 5% worst case or busy-hour throughput in Europe, for 5 GHz and 2.4 GHz bands.

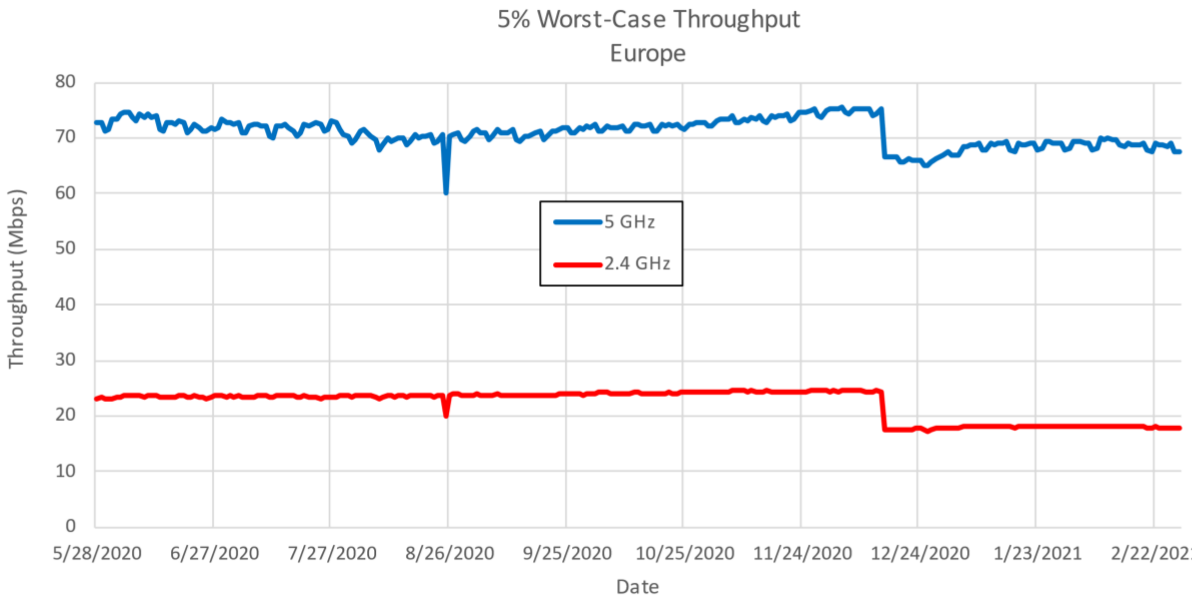

Figure 6. Europe, 5% Worst-Case Wi-Fi Daily Throughput for 5 GHz and 2.4 GHz.

3.2 Wi-Fi Transmit Rate and Throughput to Transmit Rate Ratio

Wi-Fi transmit rate is the theoretical maximum data rate, as determined by the Modulation and Coding Scheme (MCS), the channel bandwidth, guard interval, and the number of spatial streams.

The Wi-Fi transmit rate is typically collected at each station every 5 seconds. Every 15 minutes an average of the samples from all stations is uploaded and collected.

Each day the transmit rate samples are used to build a transmit rate average, in Megabits per second (Mbps) for the day. Transmit rate can be low if the stations do not have traffic.

The histograms of Wi-Fi transmit rate with 100 bins have:

- For 2.4 GHz, 4 Mbps span per bin with a maximum value of 400 Mbps.
- For 5 GHz, 20 Mbps span per bin with a maximum value of 2000 Mbps.

Wi-Fi throughput to transmit rate ratio is the average of Wi-Fi throughput divided by the Wi-Fi transmit rate (range from 0 - 100%) calculated and recorded on a daily basis.

Wi-Fi throughput to transmit rate ratio includes the effects spectrum sharing with other APs and other users, as well as other factors such as overhead. For example, if two APs are sharing the same channel equally, then the highest throughput / transmit rate they could both achieve is 50%. Wi-Fi throughput / transmit rate further decreases with increasing congestion, interference and overhead. Throughput / transmit rate relates to what a user now gets relative to having unlimited spectrum.

The histogram values for Wi-Fi Throughput / transmit rate span 1% throughput / transmit rate per bin, for 100 bins with maximum value of 100%.

3.2.1 North America Wi-Fi Throughput to Transmit Rate Ratio Histogram

Figure 7 presents the average throughput / transmit rate percent histogram in North America for the recorded time period. It shows separate curves for 5 GHz and 2.4 GHz bands.

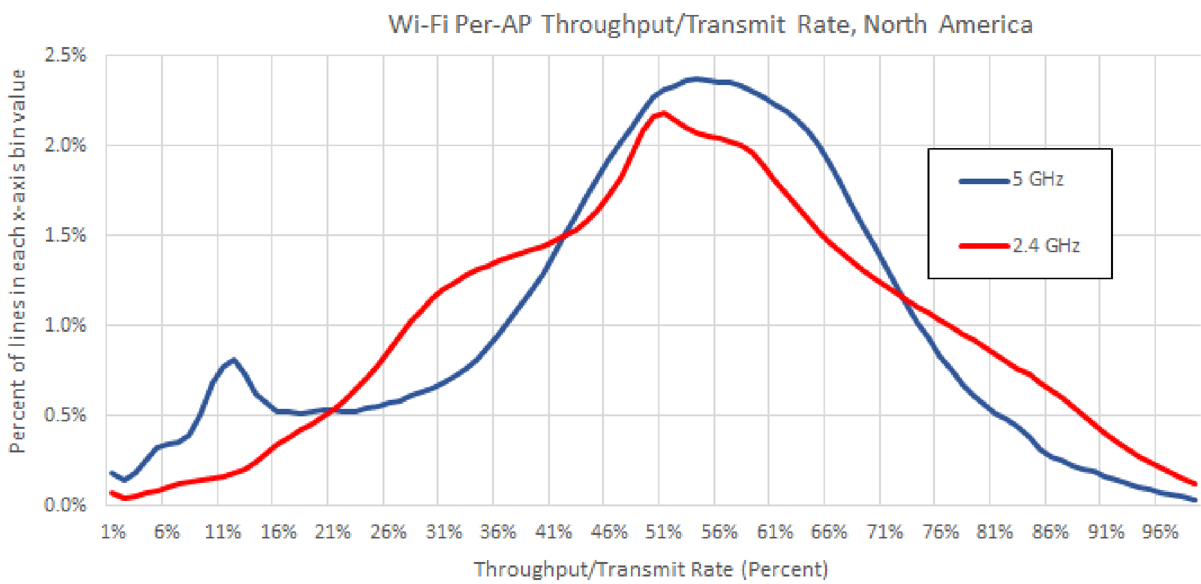

Figure 7. North America, Wi-Fi Throughput / transmit rate Histogram for 5 GHz and 2.4 GHz.

3.2.2 Europe Wi-Fi Throughput to Transmit Rate Ratio Histogram

Figure 8 presents the average throughput / transmit rate percent histogram in Europe for the recorded time period. It shows separate curves for 5 GHz and 2.4 GHz bands.

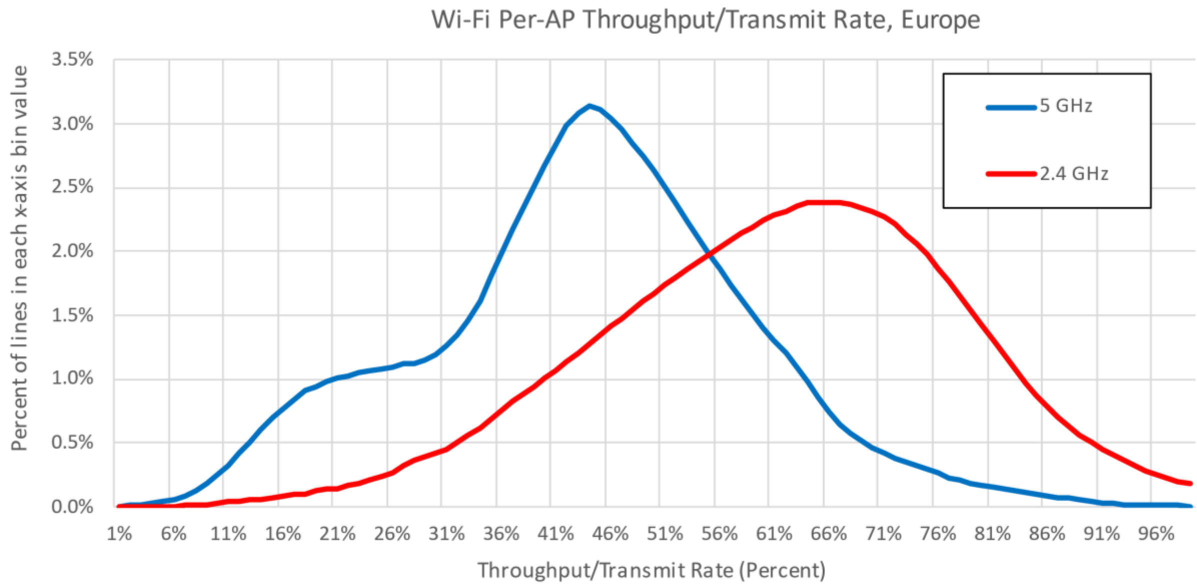

Figure 8. Europe, Wi-Fi Throughput / transmit rate Histogram for 5 GHz and 2.4 GHz.

3.3 Wi-Fi Congestion

Wi-Fi drivers periodically report if there is high congestion at the BSS. These metrics are summarized in a daily congestion detection metric that provides an indicator of the level of congestion. Wi-Fi congestion is an estimate of how much airtime is used by stations associated to this BSS, relative to how much airtime is unused. For a given associated station, congestion occurs due to Wi-Fi frames arriving at the BSS from other stations that are also associated to this BSS; these frames are addressed to the MAC address of this BSS. Congestion for a BSS is then the median across all stations.

The histogram values for this metric have two bins, one is if high congestion that may cause a problem is detected, and the other is no or little congestion detected. Congestion is probed very often in the AP, typically every 5 seconds. High congestion is declared in a 15-minute period if more than 75% of the airtime during the measurement is used by traffic to and from attached stations in at least 10% of the 5-second probe samples. If more than half of the 15-minute periods for that day are declared with high congestion, the link is deemed as highly congested for that day.

Currently the system only presents high levels of congestion, so much so that the customer would call and complain. So, few lines are shown to have high congestion here. Reporting lower levels of congestion is being investigated at this time of writing.

3.3.1 North America Daily Congestion

Figure 9 presents the percent of lines that have experienced high congestion in North America. It shows separate curves for 5 GHz and 2.4 GHz bands.

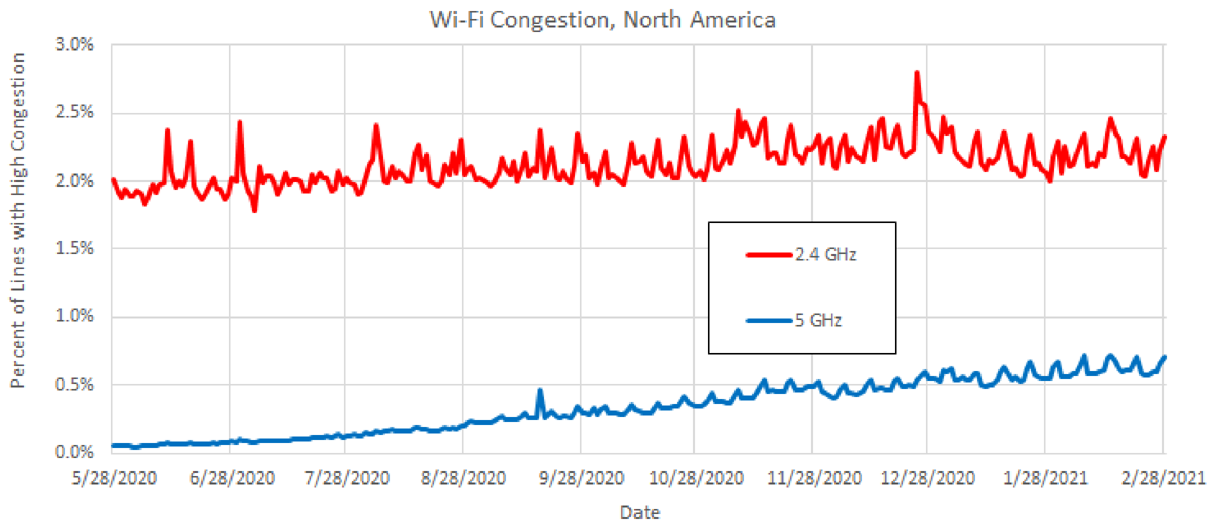

Figure 9. North America, Wi-Fi Daily Congestion for 5 GHz and 2.4 GHz.

3.3.2 Europe Daily Congestion

This figure presents the percent of lines that have experienced high congestion in Europe for the recorded time period. It shows separate curves for 5 GHz and 2.4 GHz bands.

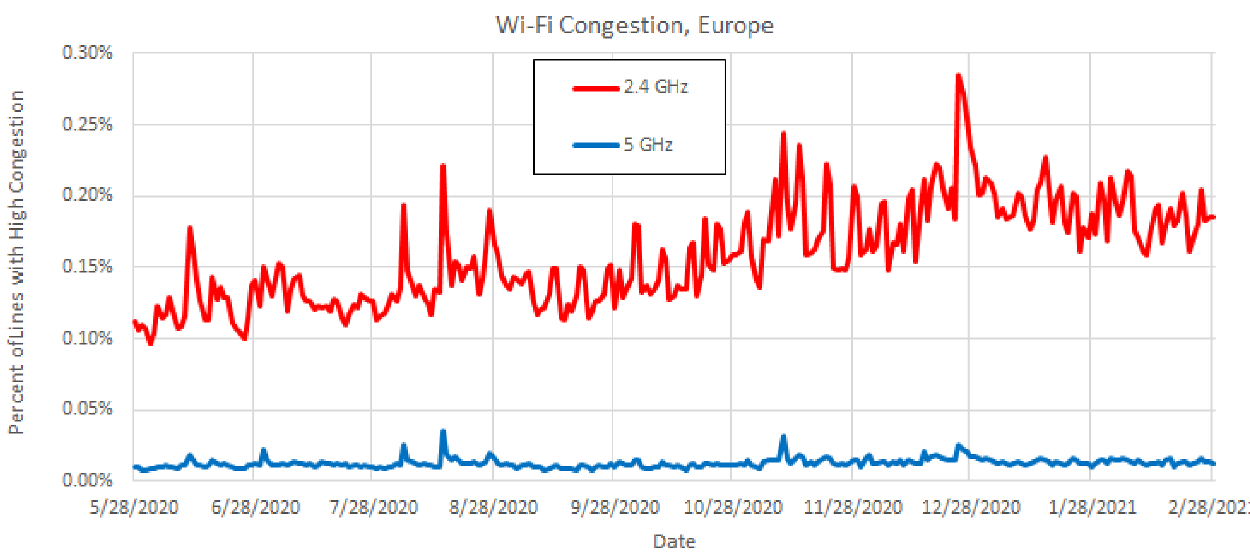

Figure 10. Europe, Wi-Fi Daily Congestion for 5 GHz and 2.4 GHz.

In addition, there is hourly congestion data, and data on CCA Idle which is a measure of the available airtime. At this time of writing, we are still researching the availability and applicability of this data.

3.3.3 Hour with Maximum Congestion

The busy hour has the maximum level of congestion among 24 hours, which can be different for each line. The percent of lines with high congestion in busy hours are plotted in Figure 11 and Figure 12.

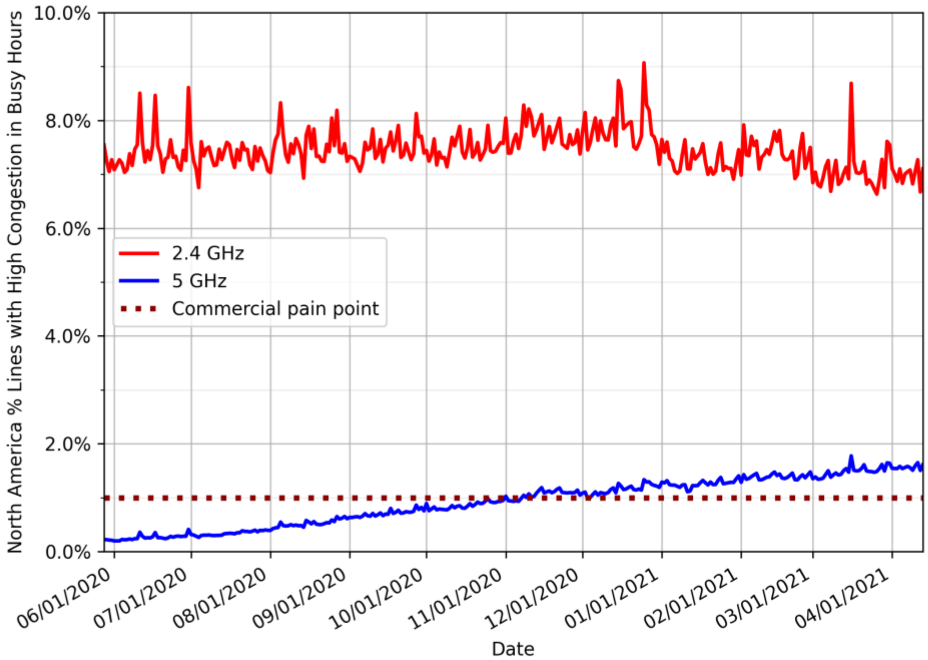

Figure 11. North America, Max Hour Wi-Fi Congestion for 5 GHz and 2.4 GHz.

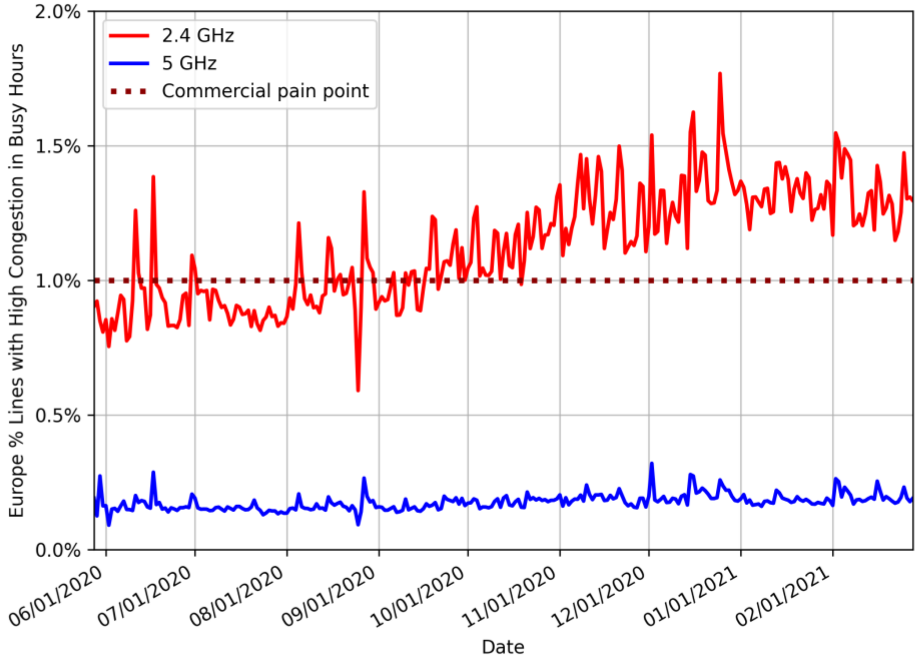

Figure 12. Europe, Max hour Wi-Fi Congestion for 5 GHz and 2.4 GHz.

3.4 Wi-Fi Interference

Wi-Fi interference presents the percent of time that the channel is not available due to interference from other APs and from unassociated stations. Interference is detected if the Clear Channel Assessment (CCA) indicates that the channel is unavailable. Interference can be measured on channels other than the current channel, however this can interrupt the user traffic.

Wi-Fi interference is typically recorded every 5 seconds on a Wi-Fi Access Point, and indicates the percent of time the Wi-Fi Access Point cannot use the channel due to interference from unassociated stations and other APs within each 5 second timeframe as reported by the Wi-Fi driver. Interference data is then aggregated hourly and daily.

The higher the Wi-Fi interference, the more interference seen on the Wi-Fi Access Point.

The histogram values for interference are recorded with histogram bins spanning 1% per bin, for 100 bins with a maximum value of 100%. Daily and hourly histograms are recorded.

3.4.1 North America Daily Interference

Figure 13 presents the CDF of North America daily interference, plotting ten bins, each bin spanning 10% of interference so that bin 1 represents the percent of lines with 0 to 10% interference, bin 2 represents the percent of lines with 0 to 20% interference, etc. Figure 13 shows data from both 5 GHz and 2.4 GHz bands.

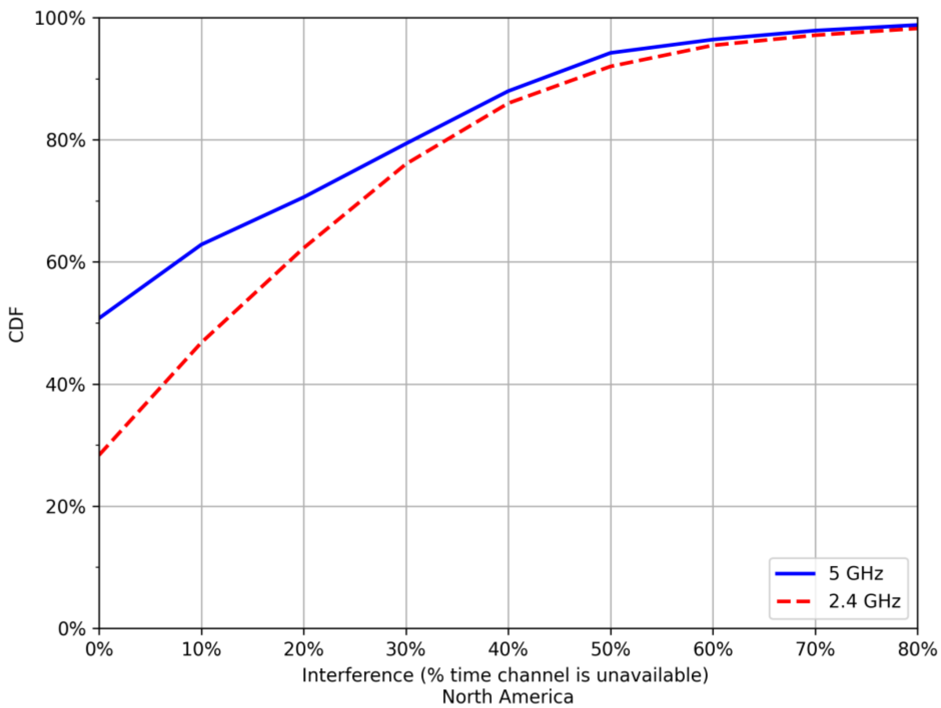

Figure 13. North America, CDF of Wi-Fi Interference for 5 GHz and 2.4 GHz.

3.4.2 Hourly Interference

The mean hourly interference in 5GHz bands in North America and Europe is presented along with mean hourly traffic in Figure 28 and Figure 29 in Section 5.3. The mean is computed as $E[x] = sum\ (x_i\ Pr(x_i))$ where $Pr(x_i)$ is given by the histogram bin values. The means were further averaged across all days in that time period.

3.4.3 Europe Daily Interference

Figure 14 plots the CDF of Wi-Fi interference in Europe in both 5 GHz and 2.4 GHz bands.

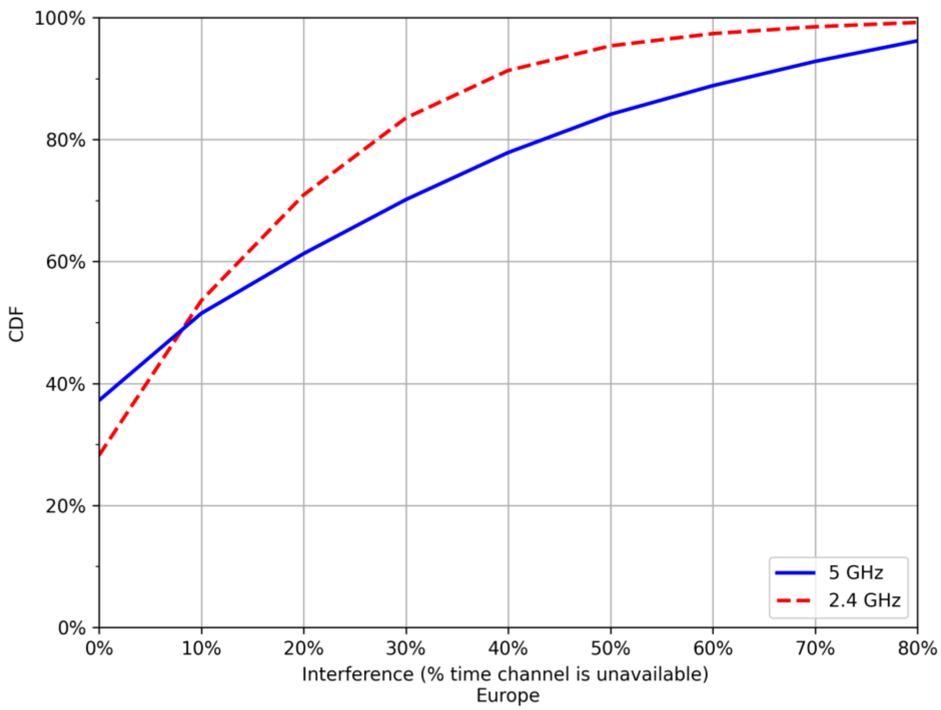

Figure 14. Europe, CDF of Wi-Fi Interference for 5 GHz and 2.4 GHz.

3.5 WI-FI TRAFFIC

Wi-Fi traffic is measured in Megabytes (MBytes) of total data over a time period and is measured both for upstream and downstream traffic in 2.4 GHz and 5 GHz bands. Wi-Fi traffic is recorded daily and hourly. The Wi-Fi traffic is measured at each Wi-Fi Access Point as the sum of all the stations traffic within a day or an hour.

The histograms for Wi-Fi traffic have 100 bins, with:

- Daily uplink for 2.4 GHz and 5 GHz are collected in 1 GByte bins with a maximum value 100 GBytes.
- Daily downlink for 2.4 GHz and 5 GHz are collected in 2 GByte bins with a maximum value 200 GBytes.
- Hourly uplink for 2.4 GHz are collected in 50 MBytes bins with a maximum value 5 GBytes.
- Hourly downlink for 2.4 GHz are collected in 100 MBytes bins with a maximum value 10 GBytes.
- Hourly uplink for 5 GHz are collected in 100 MBytes bins with a maximum value 10 GBytes.
- Hourly downlink for 5 GHz are collected in 200 MBytes bins with a maximum value 20 GBytes.

3.5.1 Daily Wi-Fi Traffic

Daily Wi-Fi traffic is plotted along with daily broadband traffic in Figure 20 - Figure 23 in Section 5.1.

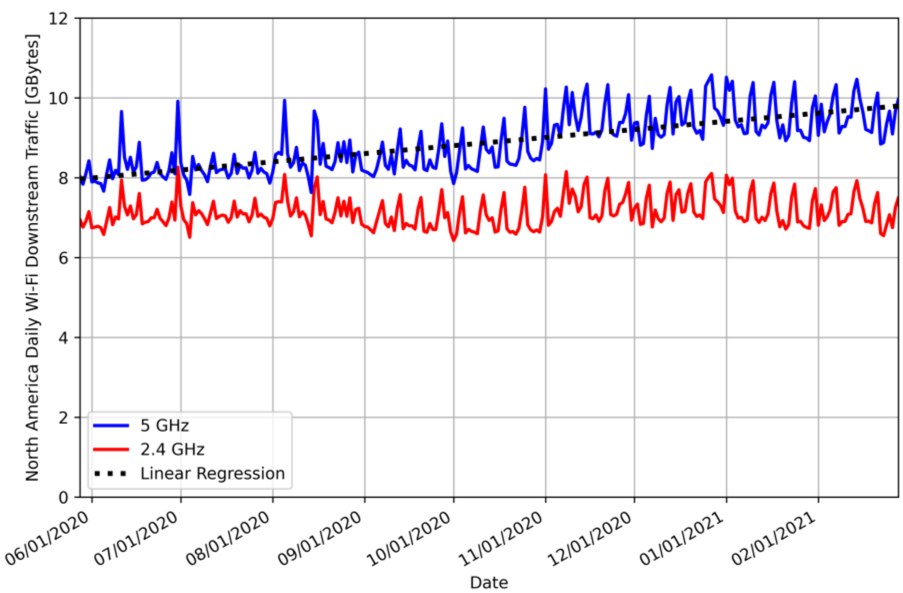

Figure. North America, Average Daily Wi-Fi Traffic.

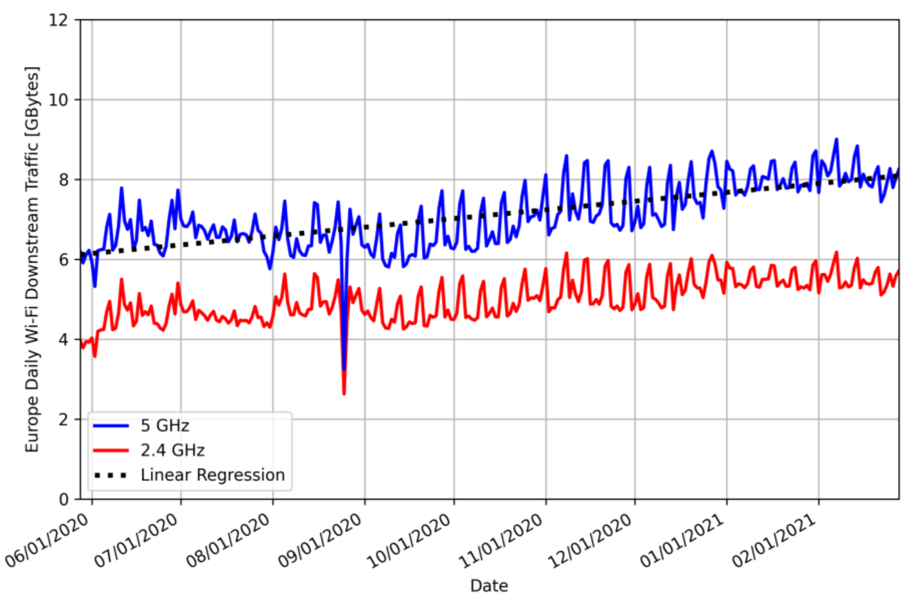

Figure. Europe, Average Daily Wi-Fi Traffic.

3.5.2 Hourly Wi-Fi Traffic

Figure 15 and Figure 16 presents the mean hourly traffic in North America and Europe for the recorded time period. These shows separate curves for 5 GHz and 2.4 GHz bands and for upstream and downstream traffic. On the plot, Hour "0" is midnight, Hour 1 is 1:00 AM, etc.

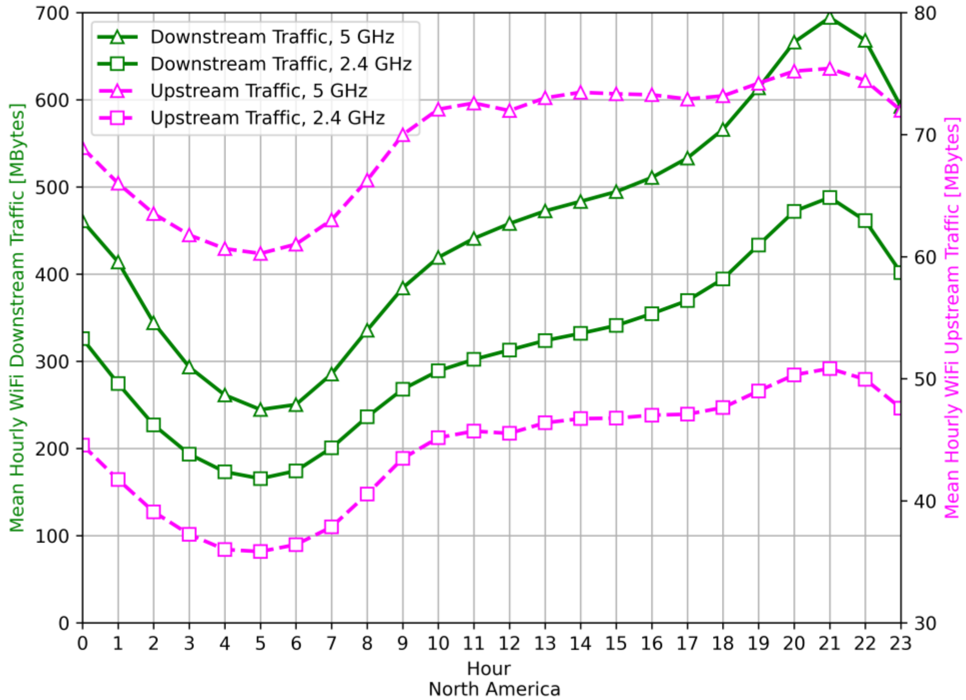

Figure 15. North America, Wi-Fi Hourly Traffic for 5 GHz and 2.4 GHz.

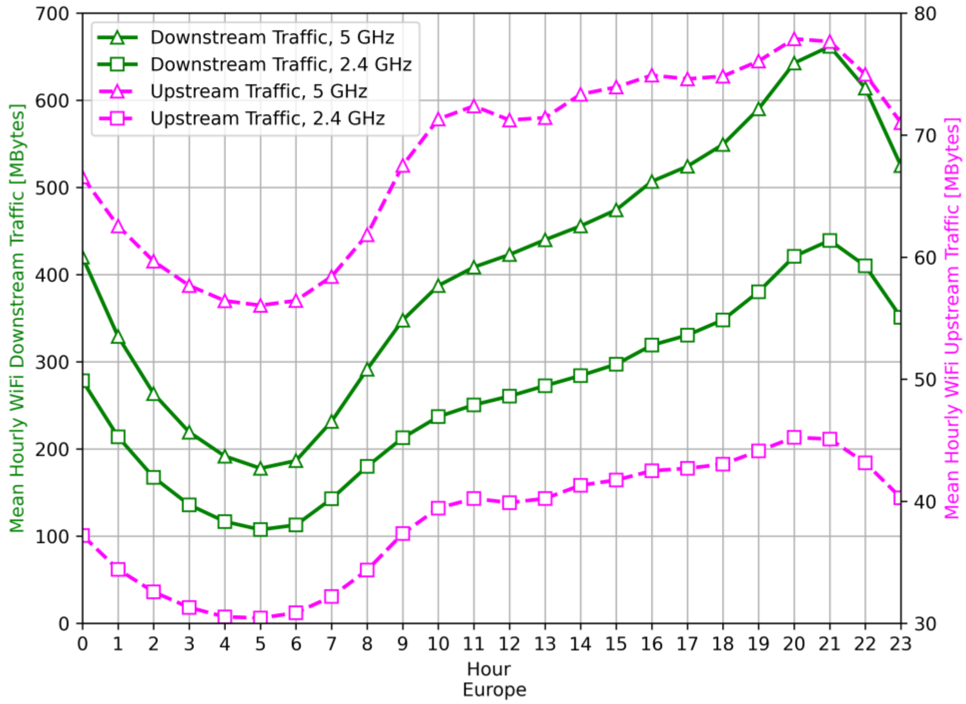

Figure 16. Europe, Wi-Fi Hourly Traffic for 5 GHz and 2.4 GHz.

3.6 Wi-Fi Latency

Wi-Fi latency is measured and recorded as a daily average in milliseconds, using round-trip latency measurements between the Wi-Fi access point and all the associated stations.

Latency histograms have 100 bins, with bin spacing 5 milliseconds, and maximum value of 500 milliseconds.

Wi-Fi Latency in North America and Europe is plotted along with broadband latency in Figure 31 and Figure 32 in Section 5.5.

4 BROADBAND DATA PARAMETERS AND PLOTS

Histograms are recorded both for North America and for Europe, for the broadband parameters shown in Table 4. The histograms have data for each day in a nine-month period from May 28, 2020, to February 28, 2021. Parameters with hourly data contain data for each of the 24 hours in each of these days. The data is collected over millions of lines.

Table 4. Broadband Parameters

Broadband Traffic	Daily and hourly, upstream and downstream
Broadband Throughput (speed)	Daily, upstream and downstream
Broadband Latency	Daily

4.1 BROADBAND TRAFFIC

Broadband traffic is measured daily (average) in Gigabytes (GBytes) for upstream and downstream traffic. The daily traffic is measured with a single metric for the day. The hourly traffic is measured the same but on an hourly basis.

The histograms for broadband traffic are recorded with 100 bins, with:

- Daily upstream in 1 GByte bins with maximum value 100 GBytes.
- Daily downstream in 2 GBytes bins with maximum value 200 GBytes.
- Hourly upstream in 100 MBytes bins with maximum value 10 GBytes.
- Hourly downstream in 200 MBytes bins with maximum value 20 GBytes.

Daily broadband traffic is plotted along with daily Wi-Fi traffic in Figure 20 - Figure 23 in Section 5.1.

Hourly broadband traffic is plotted along with hourly Wi-Fi traffic in Figure 24 - Figure 27 in Section 5.2.

4.2 BROADBAND THROUGHPUT (SPEED)

Broadband throughput (speed) is measured as the average daily throughput for upstream and downstream in Megabits per second (Mbps). The daily traffic is measured by speed tests from the Wi-Fi access point to a network-located test server and is averaged into a single metric for the day.

The histograms for broadband throughput are recorded daily with 100 bins, with:

- Upstream has bins spaced at 5 Mbps with a maximum value of 500 Mbps
- Downstream has bins spaced at 10 Mbps with a maximum value of 1 Gbps

4.2.1 North America Broadband Throughput Histogram

Figure 17 presents the CDF of throughput averaged over all days in the recorded time period in North America. It shows separate curves for upstream and downstream traffic, and Wi-Fi throughput with 2.4 and 5 GHz.

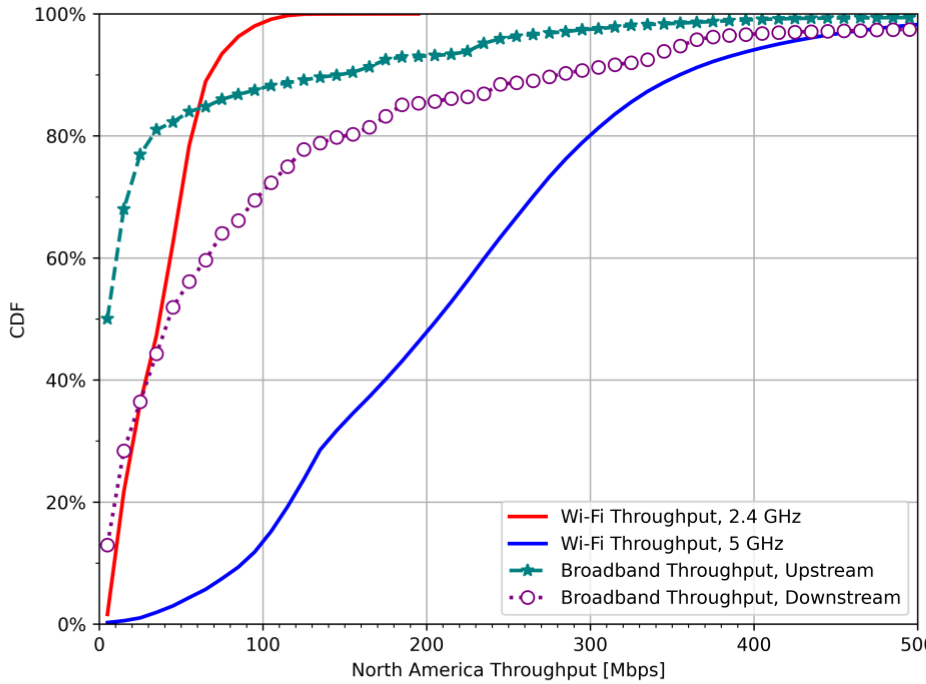

Figure 17. North America. Broadband Throughput CDF, upstream and downstream.

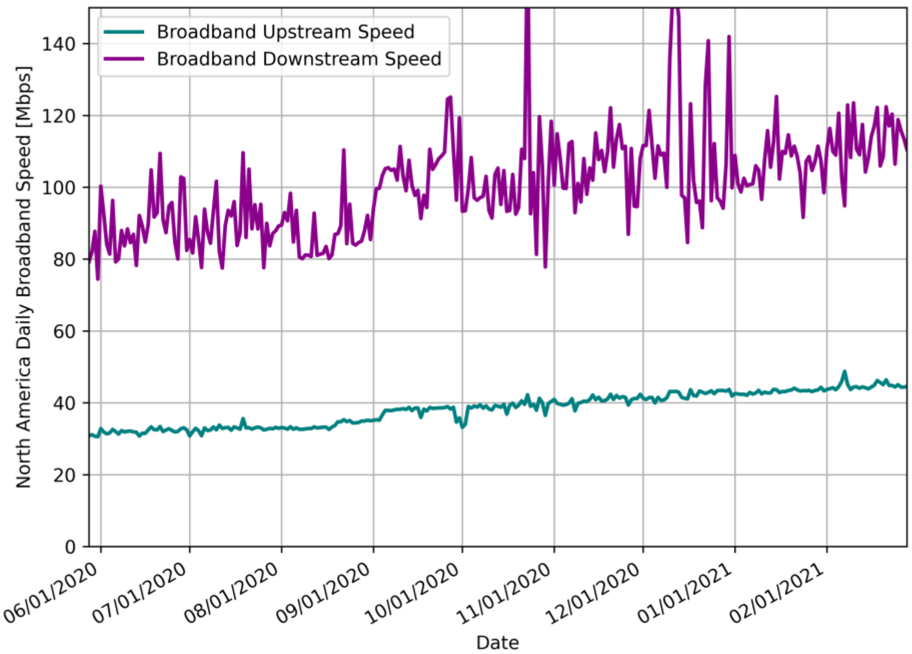

Figure 18. North America, Broadband Throughput (Speed), Upstream and Downstream.

4.2.2 Europe Broadband Throughput

Figure 19 presents the CDF of throughput averaged over all days in the recorded time period in Europe. It shows separate curves for upstream and downstream traffic, and Wi-Fi throughput with 2.4 and 5 GHz. European broadband throughput data currently presents mostly copper connections. More fiber connections are anticipated over the coming year.

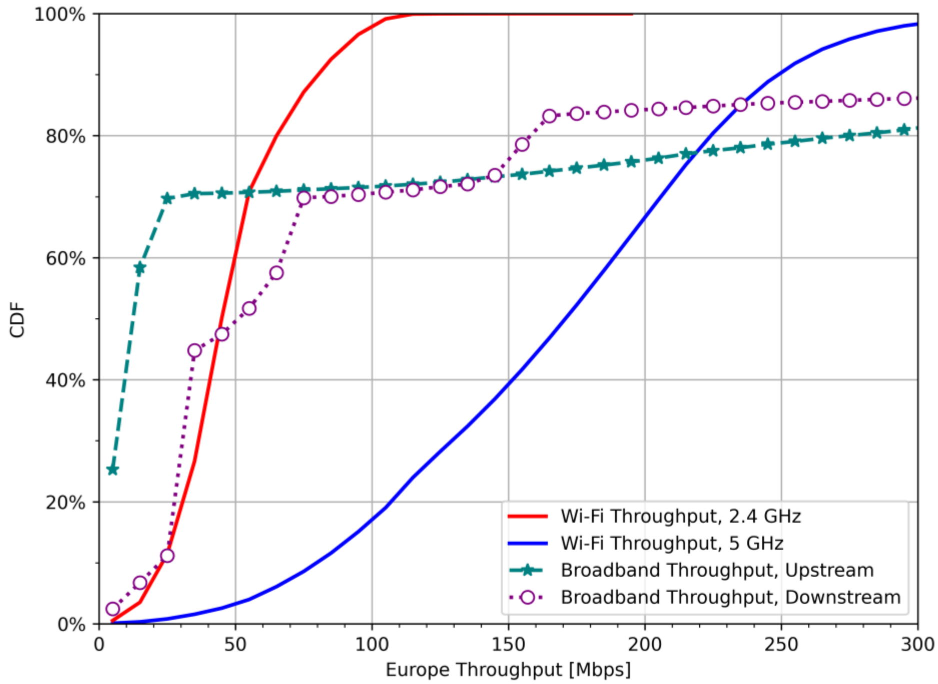

Figure 19. Europe. Broadband Throughput CDF, upstream and downstream.

4.3 BROADBAND LATENCY

Broadband latency is measured and recorded as a daily average in milliseconds, using round-trip latency measurements between the Wi-Fi access point and a network-located broadband speed test server.

Latency histograms have 100 bins, with bin spacing 10 milliseconds, and maximum value of 1000 milliseconds.

Broadband Latency in North America and Europe is plotted along with Wi-Fi latency in Figure 31 and Figure 32 in Section 5.5.

5 Combined Plots

This section shows some plots that combine related parameters.

5.1 Wi-Fi and Broadband Daily Traffic

Figure 20 - Figure 23 plot both Wi-Fi and broadband traffic. It can be seen that the average broadband traffic is approximately the sum of the average Wi-Fi traffic in 2.4 plus 5 GHz bands.

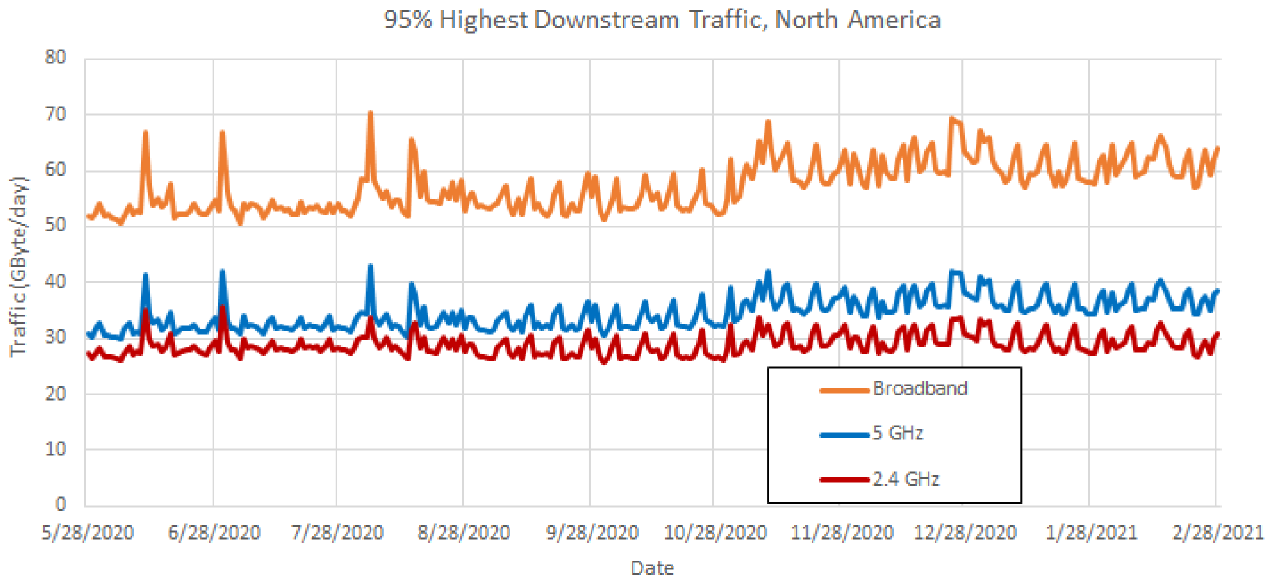

Figure 20. North America, Downstream Daily Broadband and Wi-Fi Traffic.

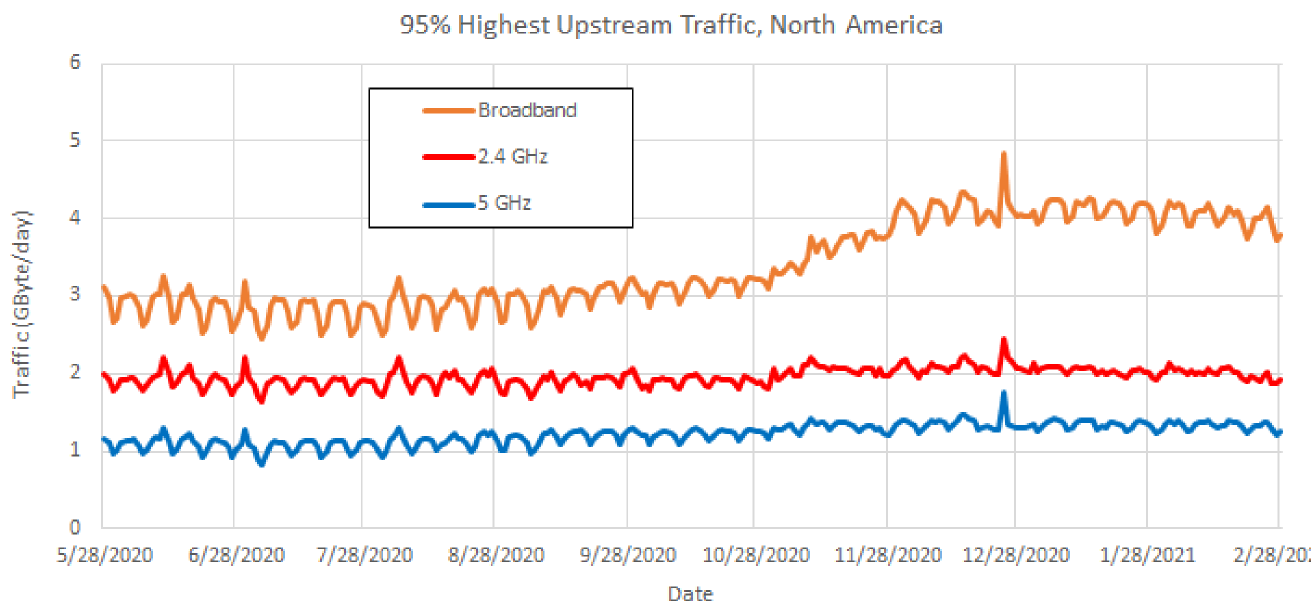

Figure 21. North America, Upstream Daily Broadband and Wi-Fi Traffic.

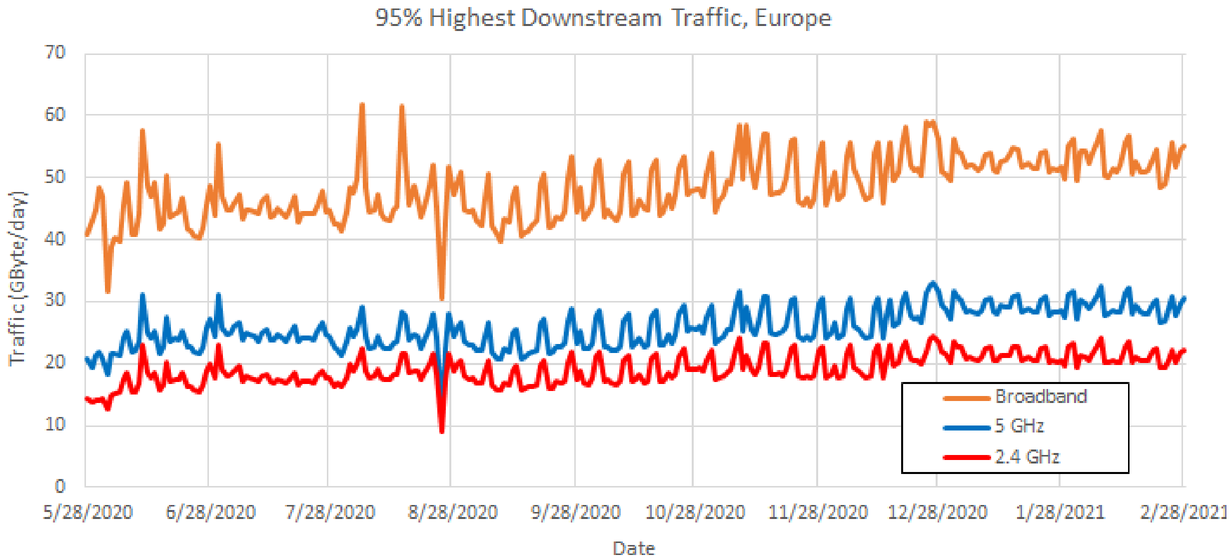

Figure 22. Europe, Downstream Daily Broadband and Wi-Fi Traffic.

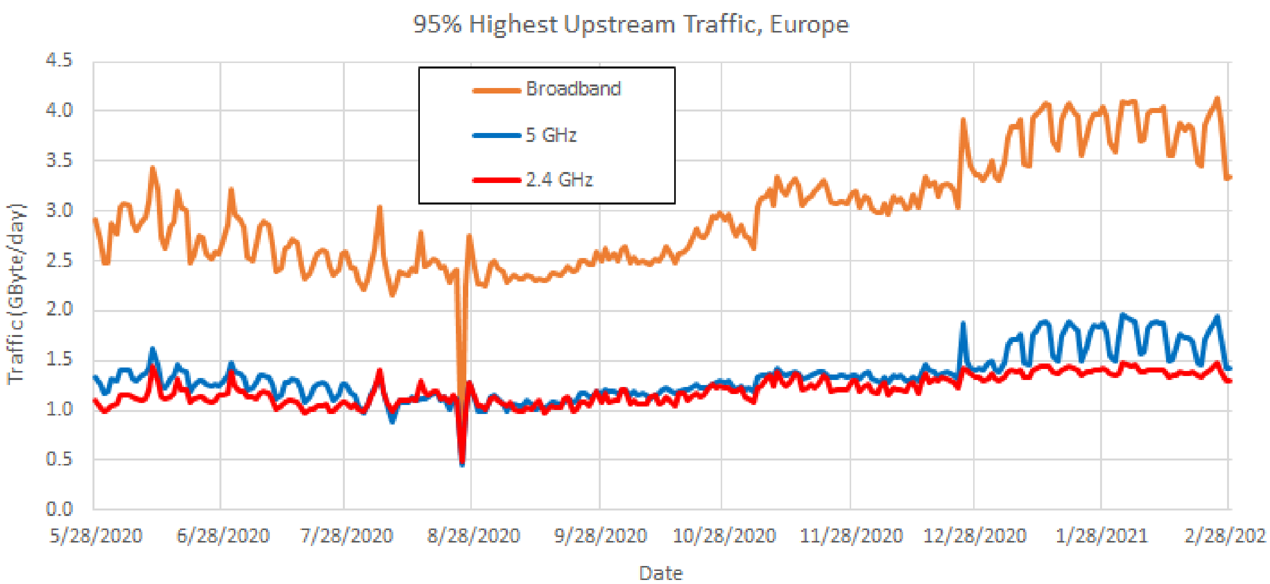

Figure 23. Europe, Upstream Daily Broadband and Wi-Fi Traffic.

5.2 HOURLY BROADBAND AND WI-FI TRAFFIC

Figure 24 and Figure 25 compare broadband and Wi-Fi hourly traffic in North America by presenting the mean upstream and downstream traffic for each hour, averaged over all days for the recorded time period. These show separate curves for Wi-Fi traffic in 2.4 and 5 GHz bands.

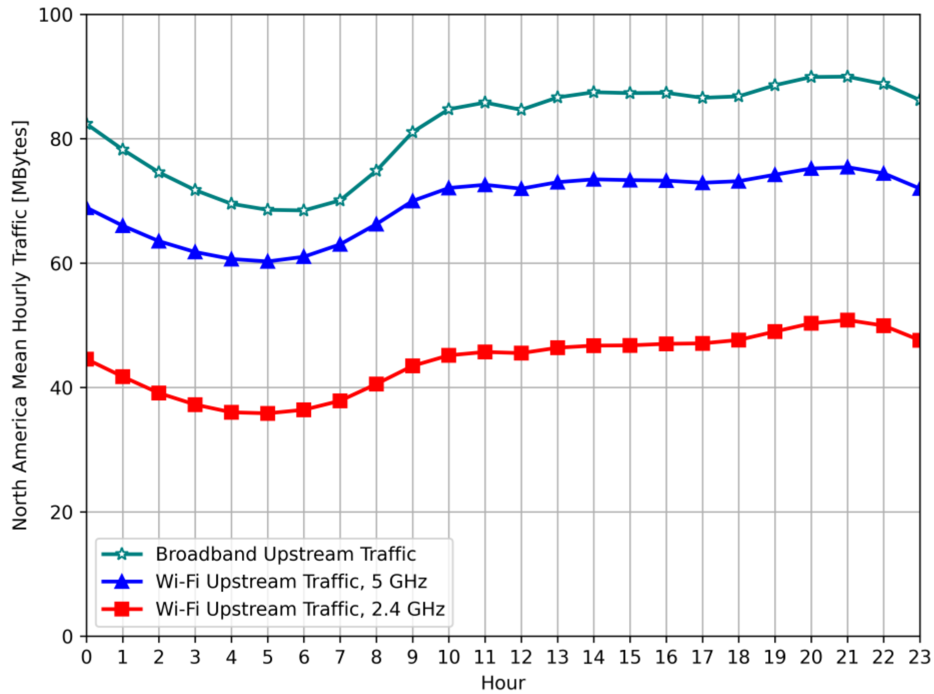

Figure 24. North America, Upstream Hourly Broadband and Wi-Fi Traffic.

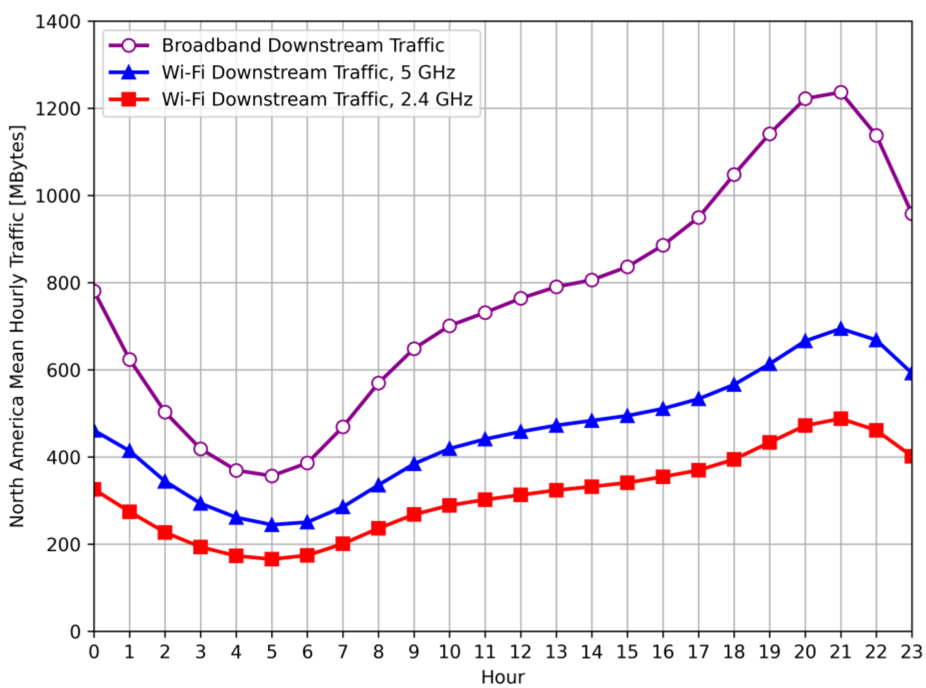

Figure 25. North America, Downstream Hourly Broadband and Wi-Fi Traffic.

Figure 26 and Figure 27 compare broadband and Wi-Fi hourly traffic in Europe by presenting the mean or average hourly upstream and downstream traffic in Europe for each hour, averaged over all days for the recorded time period.

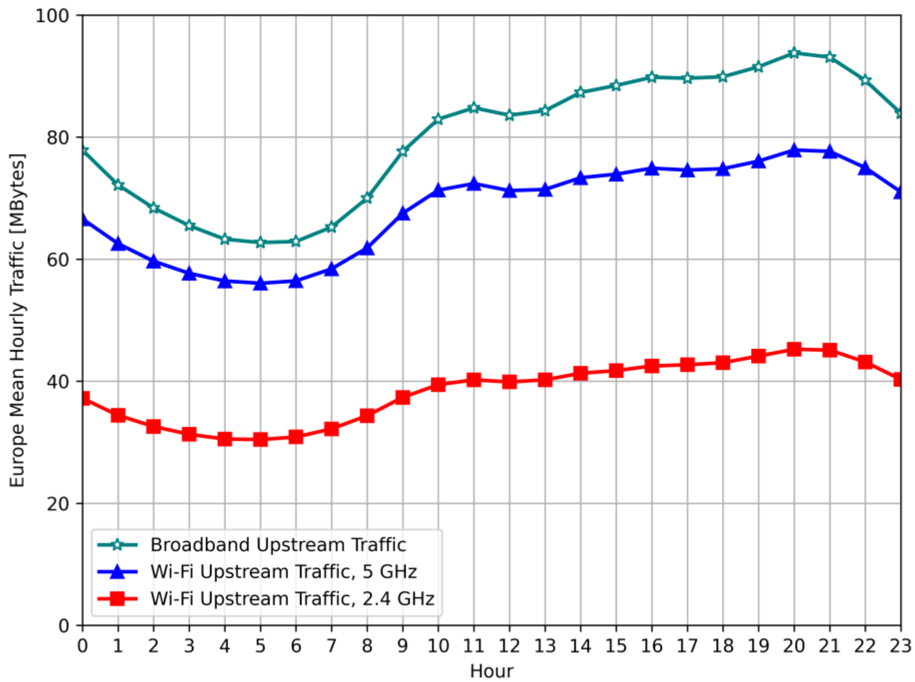

Figure 26. Europe, Hourly Upstream Broadband and Wi-Fi Traffic.

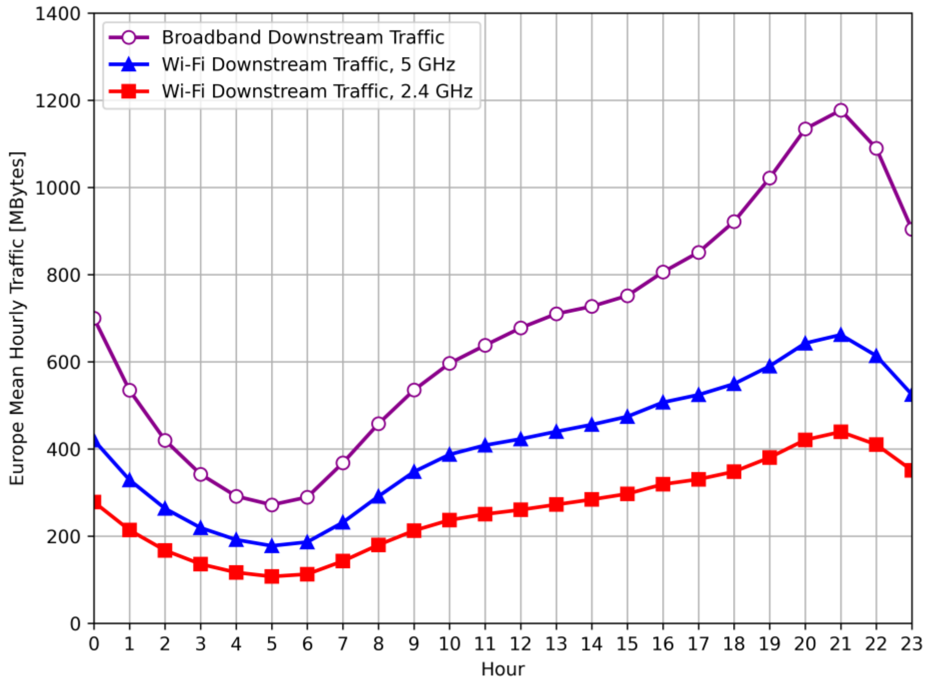

Figure 27. Europe, Hourly Downstream Broadband and Wi-Fi Traffic.

5.3 Hourly Traffic and Interference

Figure 28 and Figure 29 show hourly traffic and interference in the 5 GHz band in North America and Europe. These shows a positive correlation between downlink traffic and interference score over the time of day (the left and right y-axes correspond to downstream traffic and interference, respectively.). Quantifying correlations between these and other parameters can be the subject of future work.

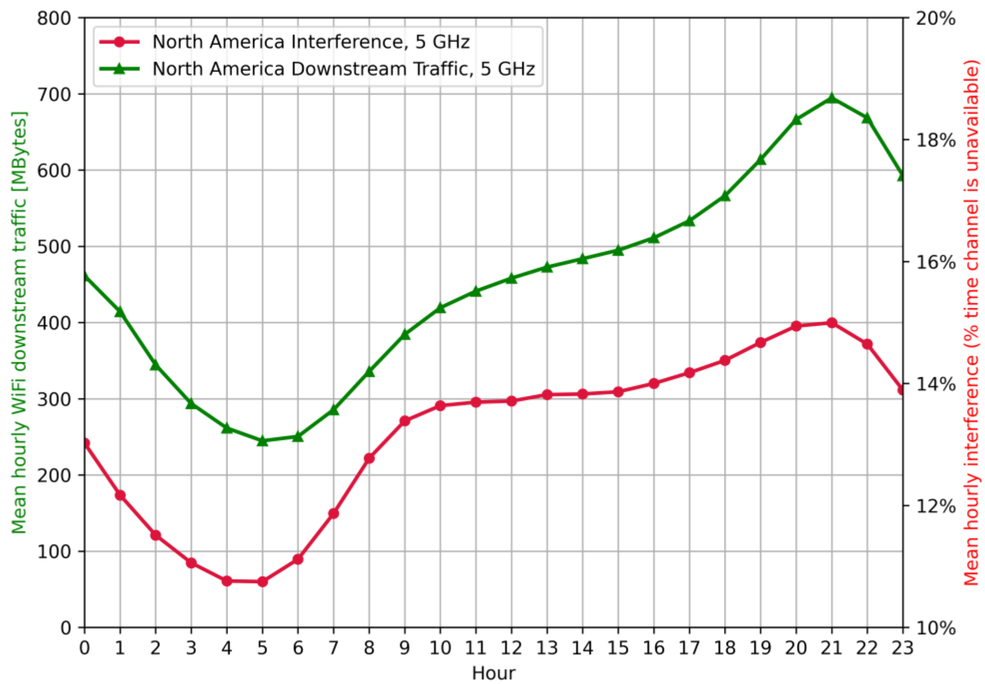

Figure 28. North America, Wi-Fi Hourly Downstream Traffic and Interference.

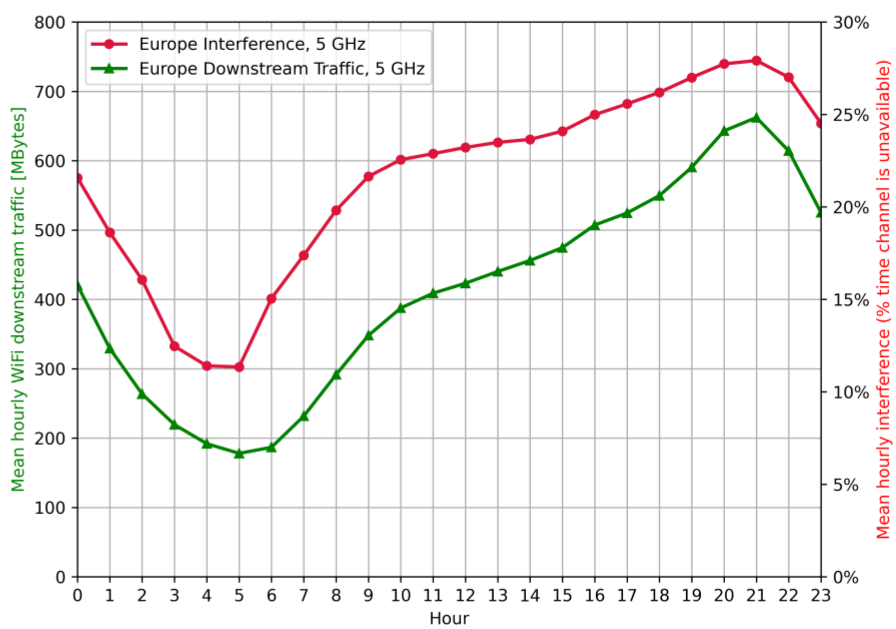

Figure 29. Europe, Wi-Fi Hourly Downstream Traffic and Interference.

5.4 WI-FI TRAFFIC AND CONGESTION

Figure 30 shows North American downstream traffic and congestion in the 5 GHz band. Much of the variation is due to weekly effects. The figure shows that both traffic and congestion are increasing over time.

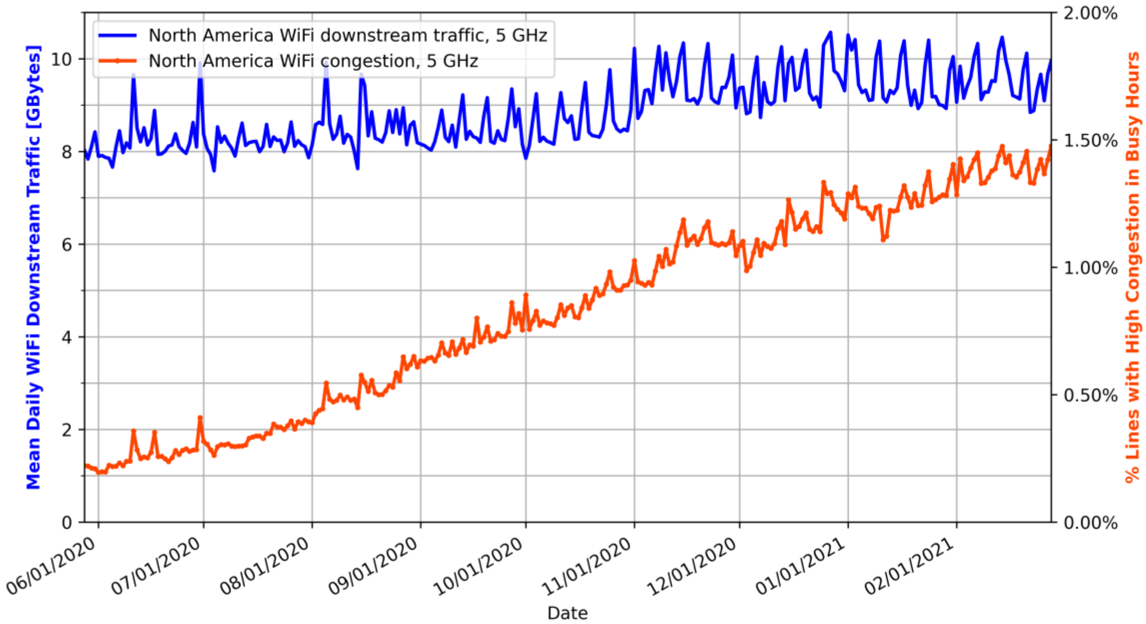

Figure 30. North America Downstream Traffic & Congestion.

5.5 BROADBAND AND WI-FI LATENCY

Figure 31 and Figure 32 show the daily average broadband and Wi-Fi latency on lines in North America and Europe over the time period.

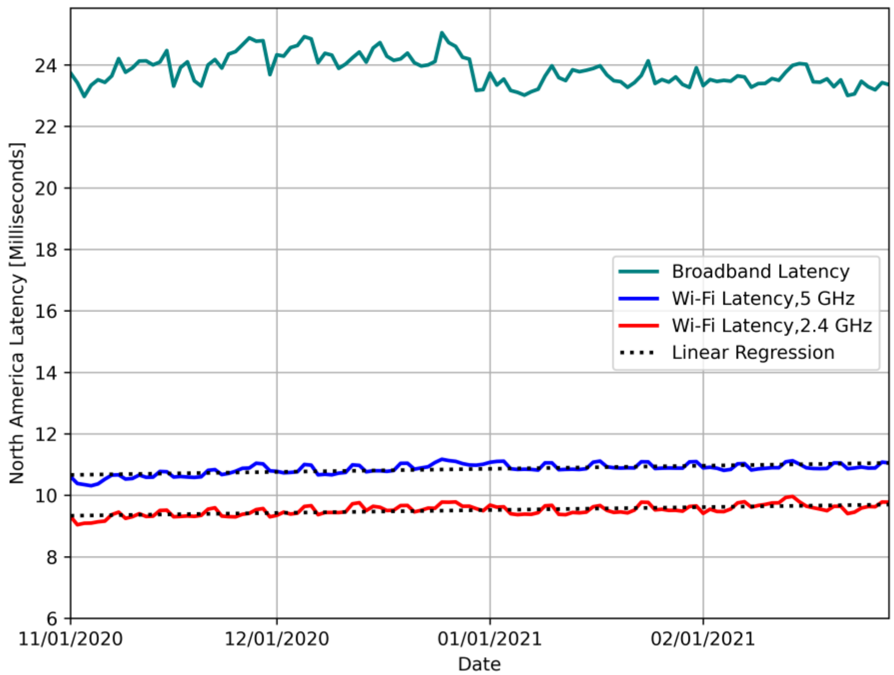

Figure 31. North America, Daily Broadband and Wi-Fi Latency.

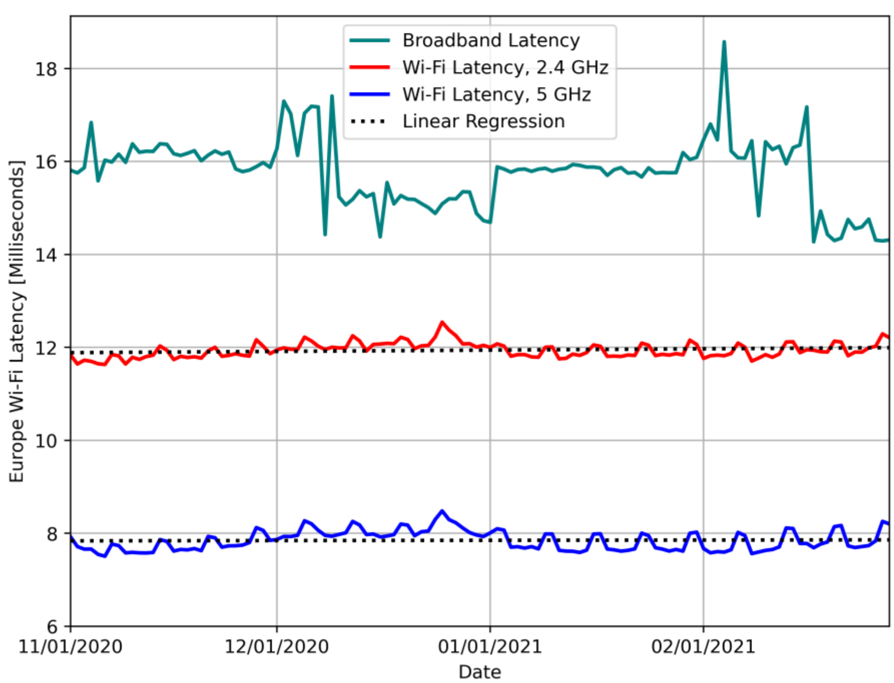

Figure 32. Europe, Daily Broadband and Wi-Fi Latency.

5.6 Interference Statistics

Figure 33 shows the average (or mean) Wi-Fi interference in Europe in the 2.4 GHz and 5 GHz bands. Here, the mean is computed as $E[x] = sum\ (x_i Pr(x_i))$ where $Pr(x_i)$ is given by the histogram bin values.

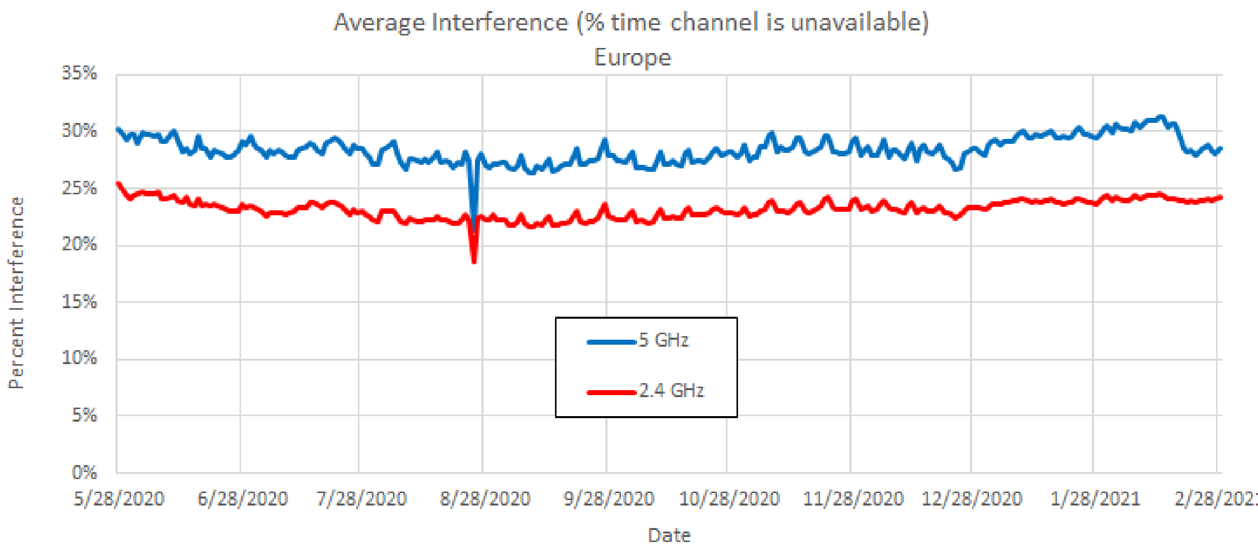

Figure 33. Europe, Average or Mean Wi-Fi Interference, 5 GHz and 2.4 GHz.

Figure 34 shows the median of the Wi-Fi interference in Europe in the 2.4 GHz and 5 GHz bands. The median is the point at which 50% of the interference is below this point, and 50% is above, as computed from the histogram.

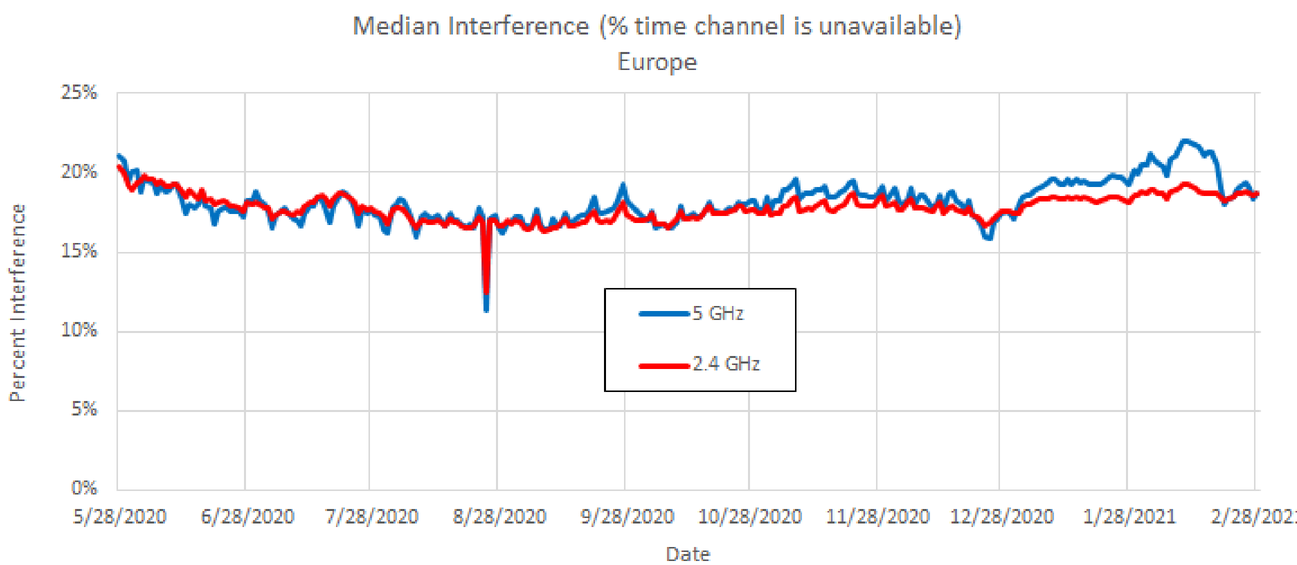

Figure 34. Europe, Wi-Fi Median Interference, 5 GHz and 2.4 GHz.

Figure 35 shows the 95% worst case Wi-Fi interference in Europe in the 2.4 GHz and 5 GHz bands. The 95% worst case is the point at which 95% of the interference is below this point, and 5% is above, as computed from the histogram.

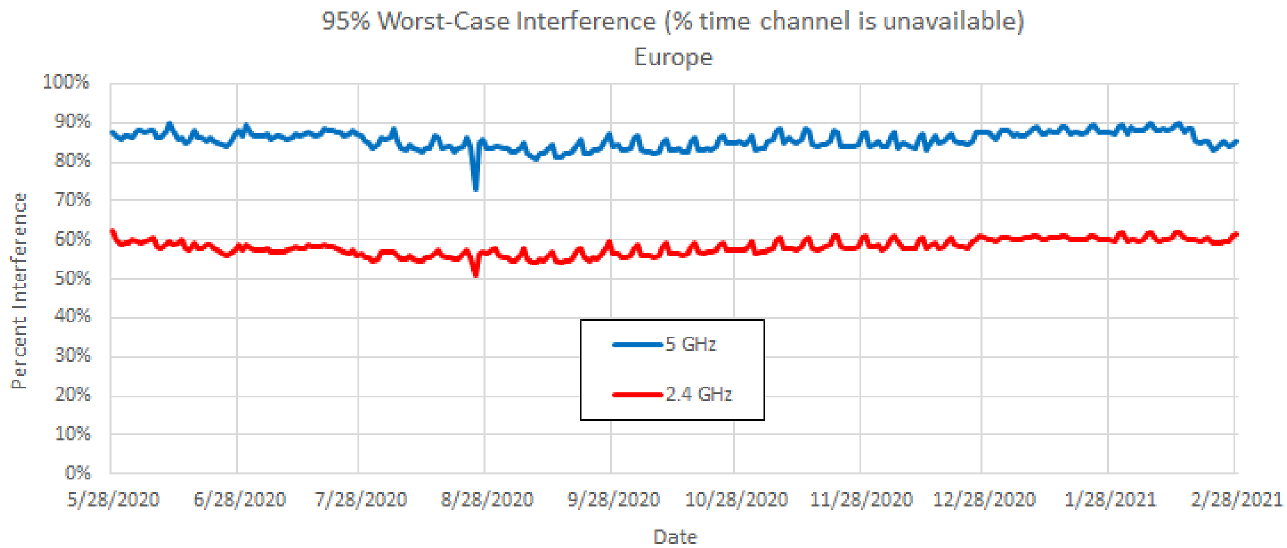

Figure 35. Europe, Wi-Fi 95% Worst Case Interference, 5 GHz and 2.4 GHz.

5.7 5 GHz U-NII Bands

Figure 36 and Figure 37 show Wi-Fi traffic and the number of connections in different 5 GHz sub-bands for North America.

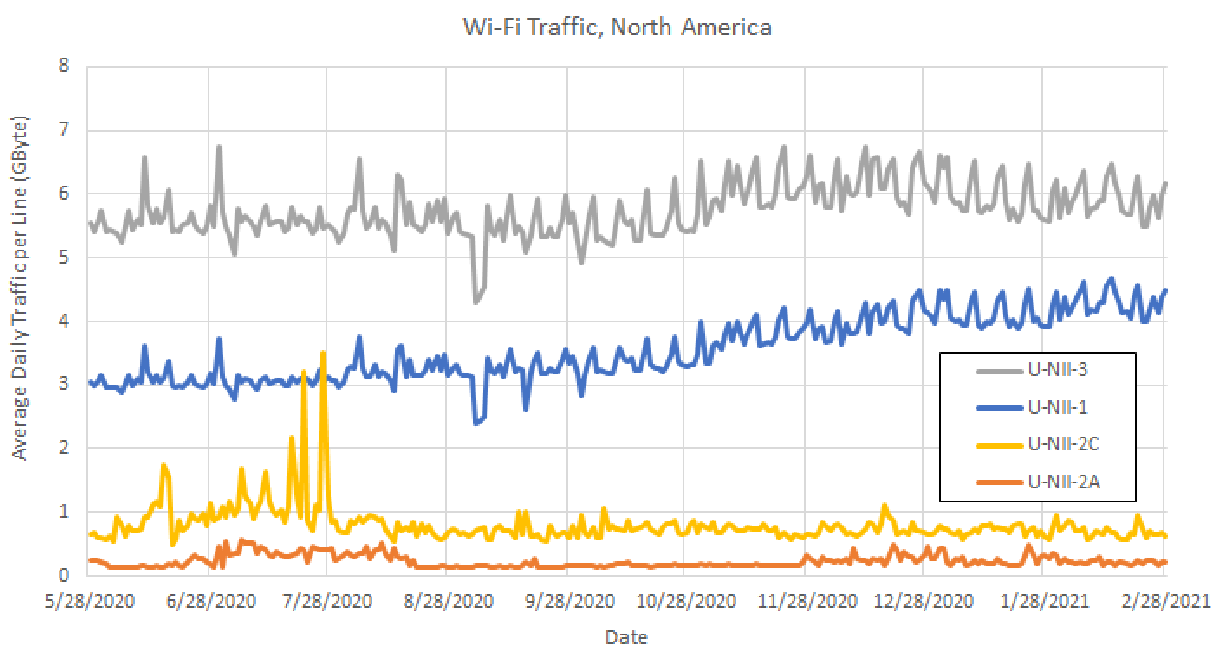

Figure 36. Average downstream Wi-Fi traffic in 5 GHz sub-bands, North America.

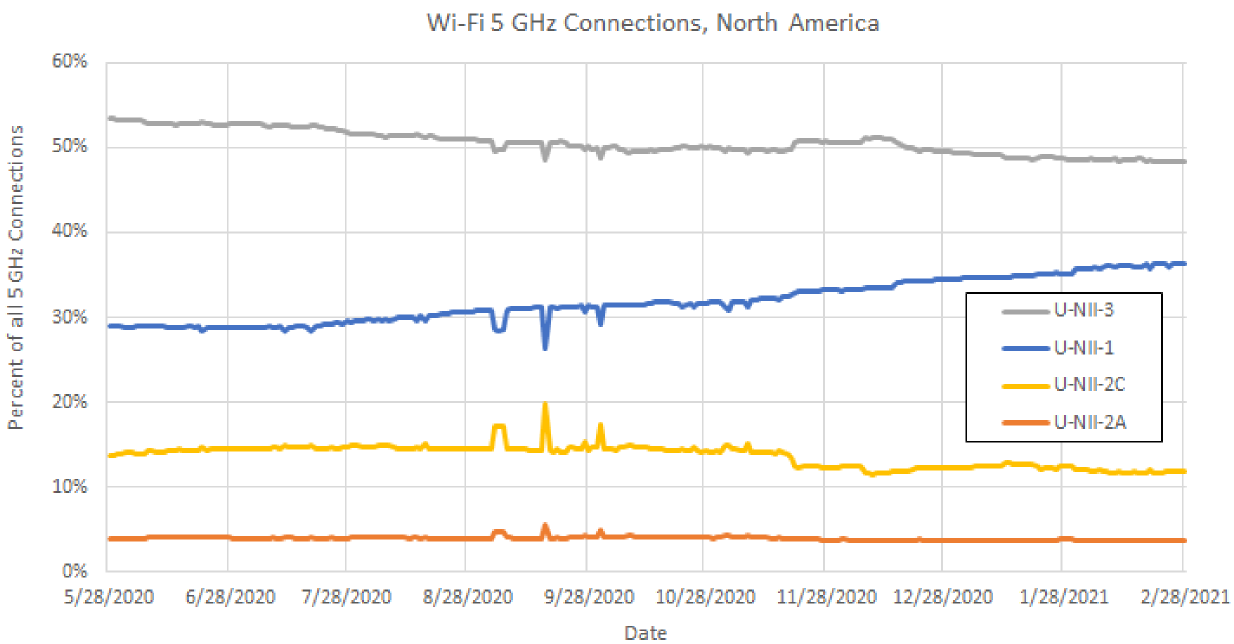

Figure 37. Percent of connections using each 5 GHz sub-band, North America.

5.8 Wi-Fi versus Broadband Access Throughput

Wi-Fi throughput was measured separately in 2.4 and 5 GHz bands via speed tests. Broadband access throughput was measured separately upstream and downstream via speed tests. Assuming that Broadband speed and Wi-Fi speed are independent, their joint histogram was used to determine the probability that Wi-Fi speed is below broadband speed and is shown in Figure 38 for North America. At this time of writing, some additions to the European data are pending which should allow a similar analysis of Wi-Fi versus broadband speed for Europe.

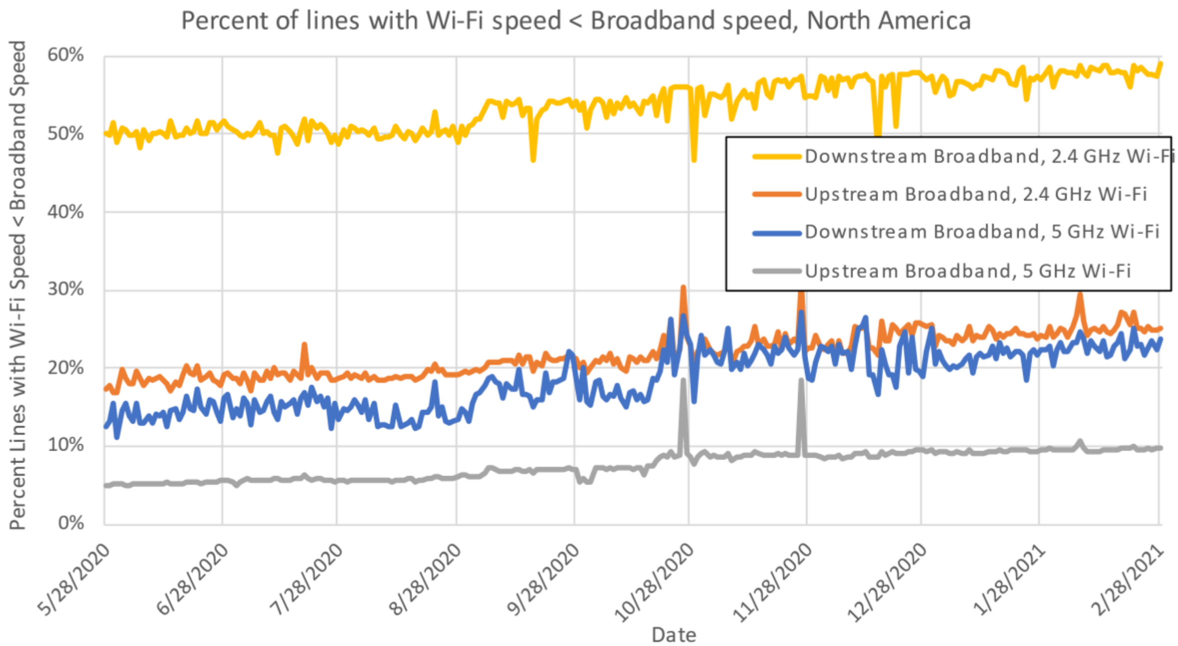

Figure 38. Wi-Fi throughput compared to broadband throughput North America.

Note that often Wi-Fi is slower than broadband, particularly for delivering broadband downstream using 2.4 GHz Wi-Fi. Broadband access often provides slower upstream than downstream, whereas Wi-Fi is roughly symmetric. Therefore, for upstream, Wi-Fi is usually faster than broadband, and so the Pr(Wi-Fi speed < broadband speed) is low in the upstream direction.

The trends over time of the above figure were found by linear regression. As shown in Table 5, the trend of Wi-Fi being slower than broadband is increasing, with the highest increase seen for downstream broadband compared to 5 GHz Wi-Fi.

Table 5. Percent annual increase in the probability that Wi-Fi is slower than broadband.

Broadband vs Wi-Fi throughput	Annual additional percent of lines with Wi-Fi slower than broadband
Upstream Broadband, 2.4 GHz Wi-Fi	10.9%
Upstream Broadband, 5 GHz Wi-Fi	7.4%
Downstream Broadband, 2.4 GHz Wi-Fi	13.0%
Downstream Broadband, 5 GHz Wi-Fi	14.4%

5.9 Overall Spectrum-Need Score

Salient Wi-Fi performance parameters which indicate how much spectrum is needed for Wi-Fi were amalgamated into a "Spectrum-need score." This score combines the best parameters for predicting the need for more spectrum:

- Wi-Fi traffic, downstream and upstream (Section 3.5.1). Increasing traffic directly indicates increasing usage.
- Wi-Fi interference (Section 3.4). Increasing interference indicates that transmissions from others on the same channel are increasingly crowding the shared spectra.
- Wi-Fi latency (Section 3.6), Increasing latency indicates that the Wi-Fi channel is increasingly occupied and so users must wait to gain access.
- Throughput / transmit rate (Section 3.2). Decreasing throughput / transmit rate indicates that each AP can gain access to a diminishing proportion of the channel time.

These are linearly combined with equal weight. The 5% worst-case point is used for each parameter; 5% of the lines have worse parameter values than this line. Many lines have excess capacity at many times in the day; and it's the stress points which are of interest.

More formally, the following parameters are combined with equal weight:

1. 95% highest downstream Wi-Fi traffic (Section 3.5.1)
2. 95% highest upstream Wi-Fi traffic (Section 3.5.1)
3. 95% highest daily interference (Section 3.4)
4. 95% highest Wi-Fi latency (Section 3.6), and
5. 5% lowest throughput / transmit rate (Section 3.2).

An increase in the first four of these indicates an increasing need for more Wi-Fi spectrum. The last parameter is inversely related; a decrease in the last parameter, the throughput / transmit rate, indicates that capacity is being limited by neighboring APs with interfering channels and so the decrease indicates an increasing need for more Wi-Fi spectrum.

For each day, each of these five parameters is scaled to a variable between 0 and 1 by dividing by its maximum value, resulting in P1, P2, P3, P4, and P5. Then the five parameters are then linearly summed with equal weight:

$$\text{Spectrum-need score} = 0.2\ P1 + 0.2\ P2 + 0.2\ P3 + 0.2\ P4 - 0.2\ P5$$

where the fifth parameter, the throughput / transmit rate, is subtracted since it is inversely related to spectrum need. This spectrum-need score is plotted in Figure 39 and Figure 40.

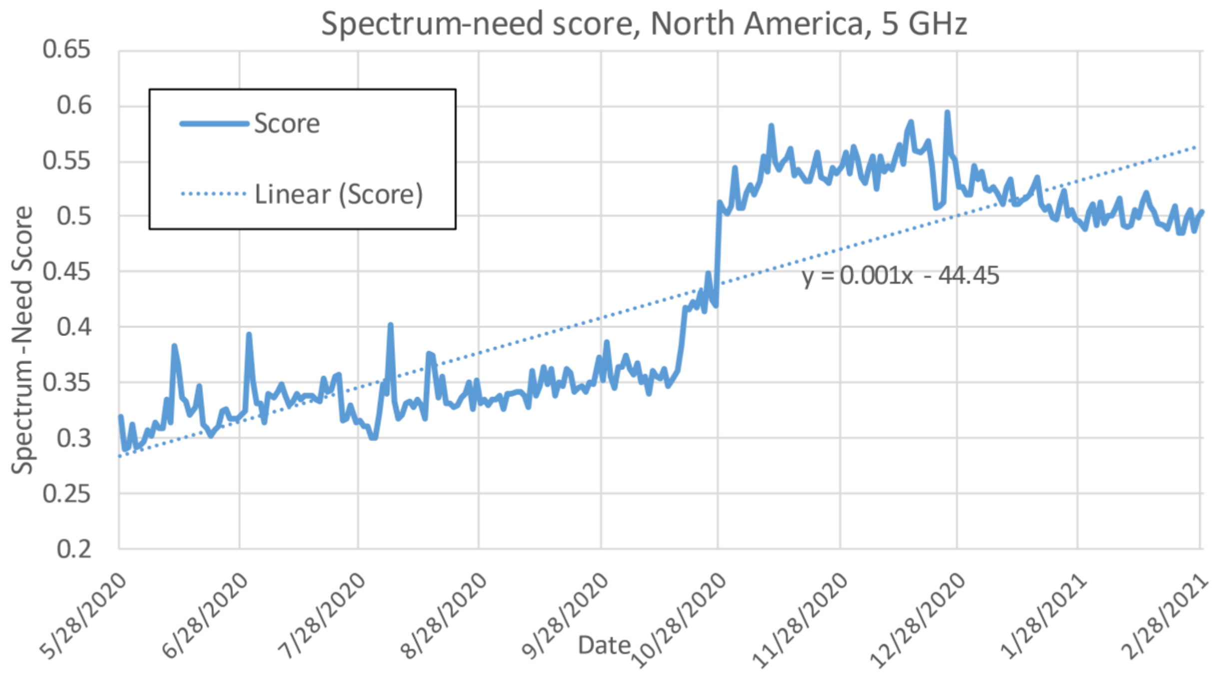

Figure 39. Spectrum-Need Score, 5 GHz Wi-Fi, North America.

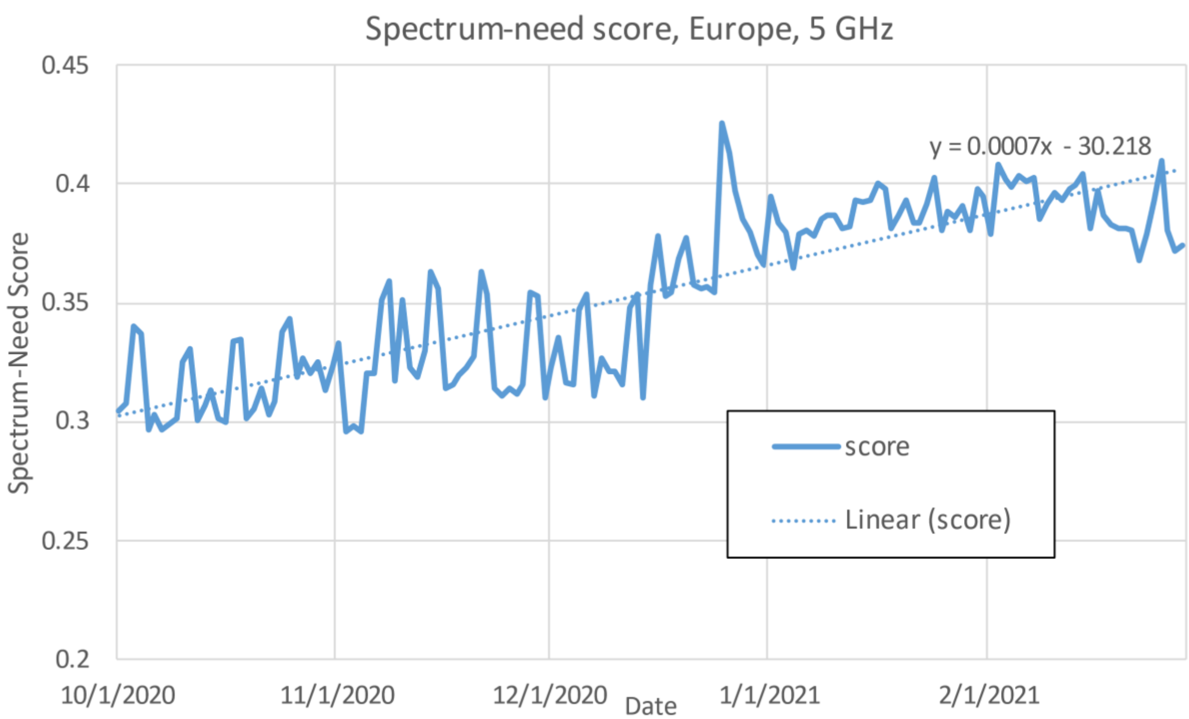

Figure 40. Spectrum-Need Score, 5 GHz Wi-Fi, Europe.

The percent annual increase in spectrum-need score was found by linear regression and is shown in Table 6. These increases are substantial.

Table 6. Percent annual increase in spectrum-need score.

Continent, Wi-Fi Band	% Annual increase
North America, 2.4 GHz	13.2%
North America, 5 GHz	37.1%
Europe, 2.4 GHz	24.8%
Europe, 5 GHz	25.3%

6 CONCLUSIONS

31 different parameters are represented in histograms, both for North America and for Europe. Data for North America includes the USA and Canada, but does not include Mexico. These can be used to compare Wi-Fi in 2.4 GHz and 5 GHz bands. Data shows that 5 GHz currently carries much traffic, and that traffic and interference at 5 GHz is often as high as in 2.4 GHz.
Thus, results indicate that the 5 GHz band is now saturating, and more Wi-Fi spectra is needed. Rapidly growing traffic results in increased congestion and interference, which can be mitigated by wider channels and more channels to reduce congestion and interference, respectively.

Significant increasing trends in spectrum need were found for both 2.4 GHz and 5 GHz bands. The annual increase in 5 GHz band is higher than 2.4 GHz band in North America and Europe.

Table 1 and Table 2 in the introduction show annualized trends in the data as found by linear regression on the data here. The increases in Wi-Fi traffic, interference, congestion and latency indicate a scarcity of available spectrum.

Many other plots, trends, correlations and statistics can be gleaned from this myriad of data. Trends over the limited timespan here (9 months) show some increases in traffic, congestion and interference; however as time progresses and more data is collected these and other trends should become more accurately known and more apparent.

Correlations among parameters across lines could be examined in the future, such as determining the correlation between Wi-Fi interference and throughput per line.

While technology advances and topology evolution can increase the QoE for a given traffic density over a given spectrum, more advanced applications may increase the QoS requirements and therefore lower the acceptable traffic density. This study was conducted in North America (USA, Canada) and Europe, but please take into account that the state of the fixed infrastructure plays a role in how quickly spectrum is required for Wi-Fi. This report indicates that in North America and Europe, Wi-Fi is quickly becoming the dominant QoE weakest link. Depending on the quality of the Fixed Infrastructure, the point in time where the QoE of the Fixed Access surpasses the QoE of the Wi-Fi link may vary from the North America and Europe examples.