Growing passenger expectations for in-flight connectivity services to be similar to those available on the ground are driving demand for higher data transmission rates from the aircraft's connectivity systems. Factors affecting the data transmission rates to the aircraft are assessed.

Data transmission rates of cabin connectivity systems

Passengers' increasing expectations for more sophisticated in-flight entertainment (IFE) activities are generating a demand for higher data transmission rates from satellite and air-to-ground (ATG) external connectivity systems. This raises the issue of what data transmission rates can be expected from different external connectivity systems. Internal connectivity systems have little impact on the data transmission rate to each seat.

Transmission rates from original external connectivity systems are enough for simpler services like e-mail and internet browsing, but higher data rates are needed for services such as live TV. In addition, passengers expect the same services in the air as they have on the ground, so more airlines feel obliged to provide complimentary internet services. Free in-flight internet access, via WiFi in the cabin, means that take-up rates are increasing at the expense of paid-for services, so higher data transmission rates are needed to satisfy passenger demand.

IFE systems

Several configurations have evolved for IFE systems, spurred by introduction of external and internal connectivity.

External connectivity systems are either via satellite communication (satcom), or use of an ATG service. Internal connectivity is through the use of WiFi signals in the cabin. These are transmitted from wireless access points (WAPs) installed in the cabin ceiling.

The traditional seatback-screen IFE system is evolving from content being sent to each seat by a hardwire connection from a cabin IFE server, to content being streamed wirelessly via cabin WiFi signals. This development has saved weight, but requires the installation of a new generation IFE system and WAPs in the cabin ceiling.

A variation of embedded IFE systems is the streaming of live content from the ground. These systems need external satcom or ATG connectivity systems.

Wireless IFE systems are a cheaper and lighter alternative to embedded ones. A wireless system will stream content to portable tablets and other devices, whether the passenger's own personal electronic device (PED), or one supplied by the airline.

Content is streamed from the on-board cabin server when internal connectivity is available. Further live content can be streamed from the ground when external connectivity is provided.

Traditional audio and visual content of IFE systems has not needed any form of external connectivity. The availability of external connectivity systems, and their growing data transmission rates, however, have made e-mail, internet access and surfing, phone calls over GSM and WiFi, text messaging, live TV, and the streaming of live audio and visual content to the aircraft all possible.

These services require increasing levels of data transmission rates. E-mail, text messaging and phone calls require the aircraft to receive a data transmission downlink rate, either via satcom or ATG, of 1-2 mega bits per second (Mbps).

Internet access and surfing require a slightly higher downlink rate of at least 3Mbps to the aircraft, as passengers browsing the internet are downloading pages only some of the time. Lower data transmission rates are needed when pages are being read rather than downloaded. Transmission rate per device or passenger will vary from 50Kbps to 150Kbps.

A similar transmission rate of 3Mbps to the aircraft is needed for live internet shopping, and credit card transactions.

Live TV requires a relatively low transmission rate to the aircraft of 1Mbps for each channel made available. High data transmission rates are, therefore, needed in most geographic areas where a large number of TV channels is available, such as the US; or where a large number of channels is needed to meet the demand for a large number of languages, such as Europe. Where 50 channels are available, as is the case with jetBlue, the aircraft needs a data downlink rate of 50Mbps.

Streaming live audio and visual content from the ground requires the highest data downlink rates of all IFE services. These are about 1Mbps per passenger, and so as much as 50Mbps to the aircraft would be needed if just 50 passengers are using the service.

External connectivity

As described, the two types of available external connectivity systems are satcom and ATG services.

ATG service

ATG services are based on data transmission from ground-based tower transmitters that provide connectivity to the aircraft overhead via cellular transmissions. The system is clearly only feasible overland. Gogo exclusively provides cellular connectivity from a network of ground-based transmitters in the US, Alaska and Canada.

Gogo has a licence for a 3Mhz bandwidth of communications, and these are sent from 200 transmitters to provide complete coverage across the continent.

There have been several versions of Gogo's ATG product. The first has a peak transmission rate to the aircraft of 3Mbps. This should be sufficient to allow the more basic services of e-mail, text,

Passenger expectations for more sophisticated in-flight services, and the increased number of airlines offering complimentary internet and WiFi services, is fuelling demand for higher data transmission rates from cabin connectivity systems.

phone calls and internet browsing.

Many North American airlines, including Delta Air Lines, American Airlines and Alaska Airlines, have subscribed to Gogo's ATG service. These carriers in turn charge passengers to use the connectivity service. Passengers can either pay per flight, or buy a larger quantity of access if they are regular customers of a particular airline. The airlines that use the ATG 1.0 service have equipped about 1,400 aircraft.

In 2012 Gogo launched a second generation of the system called ATG4. This has a higher peak data transmission rate of 10Mbps. This could theoretically allow all the basic services including internet access and browsing, plus a small number of live TV channels.

ATG is being used by United, Delta, American and Virgin America in the US, on more than 750 aircraft.

L-band satcom

L-band satcom is mainly used for flightdeck communications and connectivity. L-band provides a stable communication link because its radio waves cannot be attenuated by water droplets, but its main drawback is that it has a limited data transmission rate of only 480 kilo bits per second (Kbps).

The system can, therefore, be used for limited cabin services that only include text messaging, phone calls, and low level internet browsing.

Ku- and Ka-band satcom

Ku- and Ka-band satcom provide the highest data transmission rates for IFE.

Ku-band

Ku-band satellites are operated by companies such as Eutelsat, Intelsat, Hughes and SES. Several generations of Ku-band satellites have been launched.

None of the Ku-band satellite companies have true global coverage, so satellites cover only part of the world. Global coverage can be achieved only by using services provided by several Ku-band connectivity providers.

The satellites were first launched in the 1960s. They are configured with widebeam coverage, because they were first used for live TV transmissions, which remains their main use. Their uses have grown to include internet browsing and maritime navigation.

First generation Ku-band satellites transmit over a large area using a wide, single beam. This means they are suited for live TV, but not as well suited to the internet and aircraft which require transmissions to be concentrated in a smaller area to get higher data rates. Because live TV is the main use for Ku-band satellites, their coverage tends to be concentrated in high population areas.

Satellite operators for live TV are sub-contractors of Thales and other connectivity providers, which market the services to airlines.

The first/early generation of Ku-band satcom systems have data transmission rates of at least 1-2Mbps. Downlink rates have increased to at least 10Mbps in the case of the most recent generation Ku-band systems, and up to 30Mbps to the aircraft is believed to be achievable for standard future generation Ku-band.

The first Ka-band satellites, launched by ViaSat in 2011, are configured to provide spotbeams that transmit over a smaller land area than first generation Ku-band satellites. The power of a Ka-band transmission is more concentrated. Spotbeams provide a more suitable system for internet browsing.

Ku-band satellite providers have, therefore, launched a new generation of multiple, spotbeam high throughput satellites (HTS) systems over the past five years to provide more concentrated beam power in a particular region. Since 2001, Intelsat has launched nine new Ku-band satellites that provide spotbeam coverage.

Intelsat will launch the first HTS satellites in mid-2016, covering an area over Latin America. SES will launch its new HTS satellites soon after.

In addition to its own ATG service, Gogo provides an enhanced Ku-band service called 2Ku-band. This will have a downlink rate of 70Mbps.

Ka-band

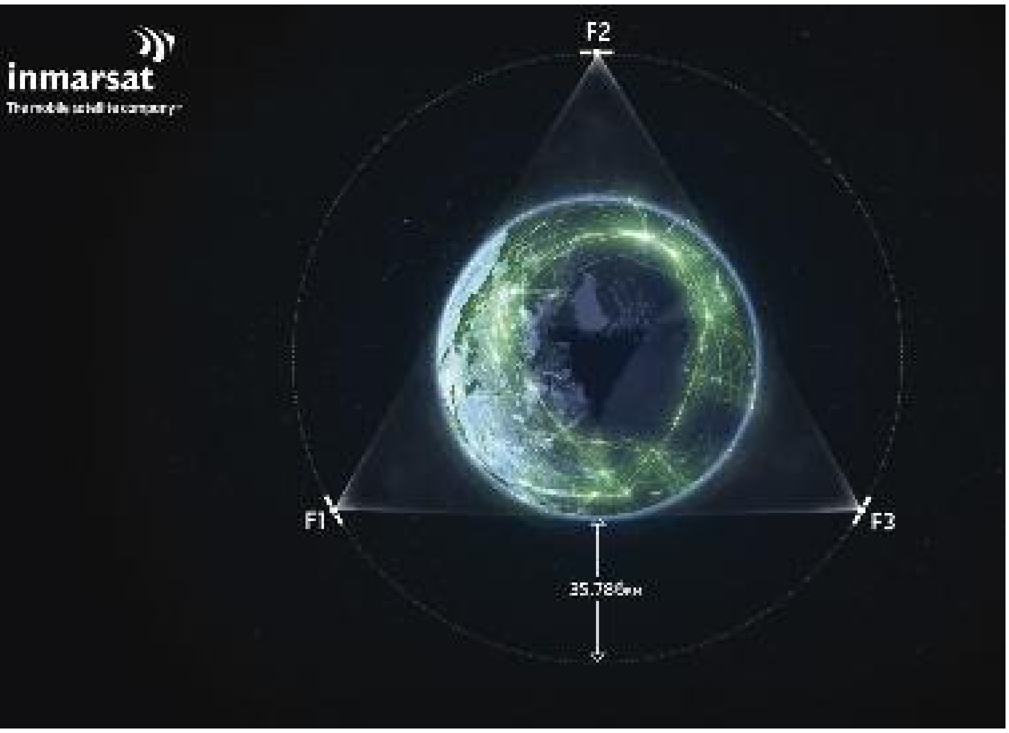
Ka-band satellites are a later generation of K-band.

Inmarsat is the only operator of Ka-band satellites to provide global coverage. Inmarsat's Ka-band service is known as Global Xpress (GX). This is provided by a constellation of four I5 satellites, the fifth generation of Inmarsat satellites, which were launched in 2013-15.

The I5 satellites are geostationary around the equator, and each one covers 120 degrees of longitude. At least three satellites are required to provide coverage around the earth's circumference. The only areas the Inmarsat satellite beams do not cover are the extreme polar regions.

The four I5 satellites may be supplemented by a fifth and sixth satellite in 2021-22. "As I5 satellites already provide global coverage, any additional satellites will be optimised to provide smaller regional capacity in areas of high demand," says David Coiley, vice president of aviation, at Inmarsat.

Each I5 satellite has 72 transponders that are simultaneously active, although the satellite actually has 89 transponders. Early generation satellites have a transponder for each spotbeam. "A transponder is the set amount of frequency being transmitted through each beam. The high demand beams of modern HTS satellites will have the equivalent of five to 10 times the number of transponder equivalents for each



Inmarsat launched high-altitude, geostationary I5 satellites between 2013 and 2015 to provide its Global Express (GX) service for Ka-band. The first three satellites provide almost full global coverage, with the exception of polar regions.

beam," says Michael Moeller, vice president of business development for connectivity and live TV at Thales. "Each beam in a GX satellite has the equivalent of a transponder of a Ku-band satellite."

Each Ka-band satellite beam is, therefore, used over an area that is a fraction of the third of the world covered by all of the satellite's beams. "The smaller the area covered by a spotbeam, therefore, the fewer aircraft operating in the area that it covers, compared to under a single wide beam provided by an early generation Ku-band satellite," says Coiley. "The smaller number of users under each spotbeam means each aircraft can get a higher data transmission rate. In addition to the standard 89 transponders and spotbeams, the I5 satellites also have six steerable, high-capacity beams. These can be moved in real time to provide more capacity in high-demand areas."

One drawback with spotbeams is that there can be data dropout as aircraft pass from the area of one beam to another beam. There is also data drop out with Ku-band satcom services.

Downlink rates for the I5 GX satellites are about 50Mbps per beam, and up to 4-5Gbps for the whole satellite.

In addition to Inmarsat's global coverage with GX, ViaSat and Eutelsat provide regional Ka-band services.

ViaSat is a Ka-band satellite provider, and has three satellites providing Ka-band coverage over the US. The first two provide a total capacity of 9 giga bits per second (Gbps). ViaSat-1 is the largest of the three satellites, and it provides coverage for all of the US, as well as most of Canada and an area of the Atlantic Ocean along the Eastern Seaboard of North America. ViaSat-1 has a capacity of 140Gbps, so the three satellites together provide a total of 149Gbps.

In 2016 ViaSat's satellite fleet will be joined by a fourth satellite, ViaSat-2. This has been built by Boeing, and will have a higher transmission capacity and cover a larger area than ViaSat-1. ViaSat-2 will cover the eastern half of North America, the Caribbean, the northern part of South America, and the North Atlantic Ocean to Europe. ViaSat-2 will have a capacity of 280Gbps. Early generation Ka-band satellites have 36 beams, while the ViaSat-1 and -2 satellites are thought to have 100-200 spotbeams.

ViaSat has also partnered with Eutelsat to provide Ka-band coverage over an extended area. Eutelsat provides Ka-band availability over Europe with its own KaSAT satellite. KaSAT was launched in 2010, and provides 90Gbps of capacity. Moeller estimates that the KaSAT satellite has about 80 spotbeams.

ViaSat's satellites have been purpose-built for internet connectivity in the US market, and so only a fraction of the capacity is used by airlines and aircraft.

Ka-band satellite companies will soon launch a new generation of satellites with more spotbeams. Each one will be concentrated on a smaller area, and so provide more capacity in that area.

Richard Nordstrom, senior director of global marketing and product management at Rockwell Collins, explains that in about six years new satellites will operate with a very large spectrum, and so have very high data rates. Each transponder will have a data transmission rate of about 500Mbps. The satellites will have multiple transponders, or nanosatellites. There could, therefore, be 600 nanosatellites in low earth orbit. These will have low latency and a high data rate and performance level.

Europe ATG system

A new ATG system, called S-band, will be launched by Inmarsat in Europe for operations in the airspace of the 28 European Union (EU) countries. This will also include the airspace over the Mediterranean, the North Sea, and the Bay of Biscay.

Inmarsat has been awarded access to a spectrum of frequencies that is provided by a new generation of S-band satellite providing European coverage, as well as a complementary terrestrial-based ATG transmitter network in Europe that is similar to Gogo's in North America.

The S-band ATG network in Europe will provide cellular transmissions. These will have transmission rates of 70Mbps in each cellular area for the ATG system.

Connectivity services

Airlines can acquire the use of one or more external connectivity services in several ways. Airlines need an external connectivity service to be economic, but able to provide passengers with a predictable and reliable service, so they request a service level agreement (SLA) from their connectivity provider. This will often be in the form of a particular minimum transmission rate to each seat for a specified percentage of the time. One way for an airline to acquire an external connectivity service is directly from the satellite or ATG operator, as is the case with Gogo's ATG service in North America.

Another way is to acquire the use of services such as Ku- and Ka-band through a connectivity provider.

Ku-band satellite operators are SES, Hughes, Intelsat and Eutelsat. Airlines acquire Ku-band from connectivity providers that include Panasonic, Global Eagle Entertainment (GEE), and Gogo. These providers will patch together global coverage from several satellite companies if an airline requires it. Gogo achieves global Ku-band coverage using satellites from SES and Intelsat.

"Thales is a connectivity provider, and we operate as a value-added reseller of Ka-band services," explains Moeller. "The Ka-band is provided by Viasat and Eutelsat, and soon by Inmarsat's GX service. We are one of five sellers of GX for Inmarsat, and we provide a line fit for Ka-band capability on the A350.

Inmarsat's I5 satellites have 89 transponders, each to provide spotbeam coverage over a concentrated area. Each spotbeam has a data transmission rate of about 50Mbps. In addition to the main spotbeams, the I5 satellites also have six steerable beams. These provide additional data capacity for high-demand areas.

"Thales is also a provider of Ku-band, which is used solely for live TV on aircraft," continues Moeller. "The Ku-band satellite live TV service is provided by Direct TV for service over the US, by Bell Express View over Canada, and by Sky Brazil for viewing over Brazil. Airlines that use this live TV service include Frontier, Westjet, Azul, jetBlue and United Airlines. We supply Ku-band for this live TV service to about 600 aircraft operated by these airlines.

"Thales provides a combination of Ka- and Ku-band to United and jetBlue in the US. The Ku-band is provided by Direct TV, and used solely for live TV. The Ka-band provided by Viasat is used mainly for internet access, and other entertainment that requires external connectivity," adds Moeller. "The United and jetBlue aircraft have two antennae, one for Ku-band and one for Ka-band."

Inmarsat's GX service for Ka-band is distributed to airlines from a number of partners or value-added re-sellers. As well as Thales, these include Gogo, SITA OnAir, Honeywell and Rockwell Collins.

Connectivity providers lease capacity from satellite companies, and there are several business models that are followed.

"Capacity from one transponder, or a fraction of a transponder, is often leased to provide service to a particular area," explains Nordstrom. "We lease capacity from Ku-band satellites, and we buy time on the system under contract."

GEE is a Ku-band connectivity provider, and it leases capacity from SES, Hughes and Eutelsat. "We lease on the basis of a full transponder or a fraction of a transponder according to our airline customers' requirements," says Jags Burhm, vice president of sales at GEE. "We provide coverage across 90% of all global air routes. The transponder can be leased for a fixed fee, which varies with the term of the contract. If it is just for a year then it is likely to be ad-hoc pricing. It is usually for a full number of years."

Leasing a transponder can cost about $1.5 million per year, which has an impact on the costs of data transmission.

There is an alternative to leasing. "A third method is for a connectivity provider or an airline to buy a certain volume of bandwidth capacity from an entire constellation over a certain period, or arrange a pay-as-you-go contract with the satellite companies," says Nordstrom. "Connectivity providers re-sell packages of satellite data volumes to airlines.

"Data capacity contracts will be long-term when leasing capacity, and medium- or long-term when buying a certain amount of bandwidth or data volume," continues Nordstrom.

The more capacity that is needed, and the longer the term, the better the rates the connectivity provider can negotiate. All the factors involved in buying bandwidth or data capacity, and leasing transponder capacity ultimately affect the cost to the airline of providing each bit of data capacity.

The business model that a connectivity provider should follow, and amount of capacity needed, require an understanding of passenger behaviour with regard to on-board services, and knowledge of the number of aircraft operated by airlines subscribing to the service that are flying in the area covered by the satellite's beam. ViaSat, for example, analyses the number of aircraft operating globally and in particular regions during the day. It also runs simulations to calculate the probability of the number of aircraft sharing a satellite beam at any one time, as well as the likely number of users on the aircraft.

This will provide an approximate idea of the capacity required, although this is constantly growing. "A connectivity providers' problem is that a vendor has to spread the cost of leasing satellite capacity over the number of aircraft using the service so that it offers the service at an economic rate," says Don Buchman, vice president and general manager of commercial mobility business at ViaSat. "This means the vendor needs to spread the capacity of the satellite beams over a large number of aircraft. The economics of using a connectivity provider can be compromised by using one that needs to lease capacity from a satellite company."

Transmission rates

Several factors affect the data downlink rates to satcom or ATG systems to each aircraft. "It depends on the capacity of the satellite or ATG system, and how it is being used," says Buchman.

Satellite configuration

The first factor that affects data transmission rate down to the aircraft is the generation and configuration of the satellite. The starting point is the frequency spectrum of the beam. Other constraints include the satellite's size and the area of its solar panels, which determine the amount of power that can be generated.

As described, there have been several generations of Ku-band satellites, and the capacity of satellites has generally increased with each generation.

"Ku-band satellites have an allocated frequency spectrum of 500MHz in each beam, so there is a difference of 500MHz between the lowest and highest frequencies in the beam," says Moeller. "One MHz roughly translates to a data transmission rate of at least 1 bit per second per Hz, but the ratio is now closer to 2 bits per second per Hz."

An early generation Ku-band satellite has a data transmission rate of 1-2Gbps. These have increased with the introduction of HTS satellites.

The significant difference in the configuration of Ka-band satellites is the use of multiple spotbeams. "Ka-band satellites have an allocated frequency spectrum of 1,000MHz. 500MHz is a reasonable amount of spectrum to include

Thales provides jetBlue with a combination of Ku- and Ka-band connectivity. The aircraft are equipped with two antennae. The Ku-band is provided by satellite operator Direct TV, and is used for live TV service. The Ka-band is provided by ViaSat, and is used for all other cabin connectivity services, including internet access.

in the traditional widebeam coverage. In the case of spotbeams, it is possible to simultaneously re-use the spectrum of frequencies in multiple beams, where the beams are not adjacent because there will be no interference between two or several non-adjacent beams," explains Moeller. "Inmarsat has different types of beams and steerable beam overlays, and a sophisticated frequency allocation plan, so the satellite can 'pump' through different service levels based on demand. With frequency re-use, a satellite with a frequency spectrum of 1,000MHz, and with 89 beams, can re-use the frequency 3-4 times, giving an effective bulk spectrum of 3,000-4,000MHz, equal to 30-40MHz per beam. The modem terminal will have a 'real 'life' limit."

Each spotbeam on a GX satellite therefore has a data transmission rate of 50Mbps, and each GX satellite can have 72 spotbeams operating at once. The spotbeam configuration means the transmission frequency can be re-used by each beam, so the satellite's 72 beams have a collective transmission rate of 3.6-4.0Gbps, covering about one-third of the world's surface. The satellites also have six steerable beams with a high capacity of 150Mbps, so they can move in real-time to high demand areas. This means that the I5 satellites have a total capacity of up to 5Gbps. "Several other factors affect the real life throughput," says Moeller. "The efficiency of the satellite, how well the airborne modem performs, the number of users in the aircraft and how the internet protocols are implemented also have an influence."

Moeller adds that a regional Ka-band satellite, such as a ViaSat-1 or ViaSat-2, has a frequency spectrum of 1MHz per beam, and so a data transmission rate of about 1-2Gbps per beam.

As described, ViaSat-1 has a capacity of about 140Gbps, ViaSat-2 about 280Gbps, and KaSAT about 90Gbps.

"These differences in data transmission rates illustrate the improved economics of new generation satellites," says Moeller. "A traditional Ku-band satellite has a build and launch cost of about $400 million, and generates a total capacity of 1-2Gbps. A new Ka-band satellite will probably have a similar cost, but provide 40 or 60 times the capacity.

The new generation HTS Ku-band satellites have a spotbeam configuration to gain a similar improvement in data transmission rates, so their data capacity should be 30-40Gbps for the whole satellite.

Beam and spotbeam area

The area covered by each spotbeam also decides the ultimate data downlink rate to the aircraft. "Spotbeams over or near the equator cover a smaller area than spotbeams over more extreme southern or northern latitudes because of the curvature of the earth," says Coiley. "Spotbeams at more extreme latitudes will, therefore, have lower data transmission downlink rates to the aircraft." The issue is made more complicated by different satellites having different sized spotbeams.

"The borders of beams are defined, and the beams overlap," says Coiley. "The aircraft's system switches between beams in real time as it flies from one area to another. This is done to get even use of the beams, although the aircraft can be logged onto two beams at once."

A single beam from a Ku-band satellite covers an area of about 20 million square kilometres or 7.7 million square miles, explains Veronique Blanc, chief technology officer at SITA OnAir. In contrast, a spotbeam from some Ka-band satellites covers an area of about 2 million square kilometres or 770,000 square miles, although the area covered depends on the latitude of the beam. This beam, therefore, has a diameter of about 1,000 miles. A spotbeam of a Ka-band satellite may cover about one tenth of the area covered by a Ku-band's widebeam.

Number of users

A further factor affecting transmission rate to each aircraft is the number of aircraft flying in the area covered by each beam, although not all aircraft flying in this area will be operated by airlines and other operators that subscribe to a satellite or ATG service.

Different areas covered by spotbeams from Ka-band, and future Ku-band satellites, will have differing levels of traffic volumes. The eastern seaboard of the US has higher traffic movement densities, while the mid-northern states have some of the lowest. Movement densities vary widely across parts of Europe, the Indian sub-continent, China, and the Asia Pacific.

The number of aircraft that are using the service, while flying under a spotbeam, will vary constantly. Peak traffic times will be in the morning and then the afternoon and evening. "It is probable that 90-140 aircraft can be operating under a beam simultaneously in North America, Europe and the Asia Pacific, where traffic density is high," says Burhm. "Some satellite providers state a limit of 500 aircraft per beam. Providers continually monitor what the data usage is by aircraft, and then decide if they need more bandwidth, or have to limit the number of users by using pricing or controlling bandwidth to each device."

Data capacity per beam, the area covered by each beam, and number of aircraft operating in the area affect the data transmission rate.

"It is too simplistic to say, however, that the data transmission rate to each aircraft is the beam's capacity divided by

The data transmission rate to each aircraft is influenced by several factors. The main ones include the widebeam or spotbeam configuration of the satellite, the frequency spectrum and data transmission capacity of the satellite beam, the area the beam covers, and the number of active users under the beam.

the number of active aircraft operating under the beam," comments Coiley. "This is first because all subscribing aircraft operating in a beam's area are not demanding the same amount of data transmission at exactly the same time. There are sharp spikes in demand. That is, pulling data for page downloads on the internet requires a lot more data than viewing downloaded pages. All the passengers who are browsing the internet are not constantly downloading pages all the time, or at exactly the same time. The demand for data from an aircraft constantly goes up and down. Also, there is not the same level of demand from each aircraft at the same time. This means data flow from a satellite gets directed to each aircraft as it demands it. An aircraft should get what it needs at any one time. The satellite network constantly adjusts the use of spectrum and capacity to the aircraft that are demanding it."

Blanc adds that satellites can use a technique called 'traffic shaping,' a flexible way to deliver data across the network. Data that correspond to interactive applications can be prioritised, for example, for internet browsing and streaming services. Non-interactive applications are given second priority, including activities such as e-mail.

The only IFE service that requires a constant data transmission rate is live TV. Each channel requires 1Mbps. The only TV service that really needs to be live, however, is sport. Other items, such as news, can in fact be preloaded onto the aircraft's server prior to the flight, or viewed via the internet. If sport is to be shown live, then multiple channels may be required, and so a data transmission rate of 10-20Mbps to each aircraft and, therefore, a powerful satellite system will be required. The cost of licensing content on TV channels showing sport is another consideration, but its high cost dissuades many airlines from providing a service.

There are a few other factors that affect data transmission rate or quality, including latency of the transmission from the satellite to the aircraft. Latency is the time delay caused by the 0.7 seconds it takes to transmit from the satellite to the aircraft. This only applies to transmissions from high orbit satellites and only affects telephone calls, however, and not the actual data transmission rate.

Another issue is the quality of the antenna on an aircraft. The size and shape of an antenna that can be placed on a fuselage is compromised by the need to have low profile antennae that incur the smallest possible fuel burn penalties.

First generation antennae have a complex multi-gimballed and mechanically steered dish. Gogo is due to launch a new generation antenna called ThinKom. This is an electronically-steered, flat-panel antenna that is lighter than current antennae available. Kymeta has a single-gimbal, mechanically-powered, dual-dish antenna.

Service level agreements

Connectivity providers offer service level agreements (SLAs) due to variable data transmission rates and demand. SLAs have guaranteed minimum data transmission rates to each seat, or a specified transmission rate for a certain percentage of the time.

Blanc says it is now generally possible to have an SLA with a minimum guaranteed level of 1-10Mbps per seat.

The more recent SLAs commit to 10-15Mbps per seat, and this comes from a total of 70-80MBps per aircraft. This is possible because two passengers are not simultaneously doing the same thing.

In the case of GEE, it supplies two Ku-band connection pipes for cabin IFE. "One is used for live TV in the US," says Burhm. "In the case of Southwest Airlines it has the Ku-band sponsored, and allows the airline to provide 25 channels of I.P. TV. The second Ku-band pipe is for the rest of the IFE systems. This includes e-mail, text messaging, social media and internet browsing. This requires 30-40Kbps per seat. Southwest charges $8 per seat, while Norwegian Airlines provides it for free.

"We do provide a SLA, and in a free or complimentary environment with a likely take-up rate of about 50% we guarantee a rate of 150Kbps to each device, and the same data rate in a paid environment where the take-up rate is likely to be about 10%," says Burhm. "Some SLAs are now based on a certain amount of time it takes to load an internet page. This has been introduced due to variable transmission rates."

Burhm adds that Ka-band satellites have higher rates than the Ku-band that GEE offers. "We expect Ka-band to provide an overall lower cost in the future. We will be happy to move to Ka-band when it becomes cheap enough."

Coiley says that Inmarsat was the first connectivity provider to offer airlines SLAs. "SLAs typically offer up to 12Mbps to the aircraft with Ka-band, although the rate can be constrained by the aircraft's antenna." Moeller adds that more airlines are now requiring rates of 20Mbps and higher, and the level will continue to increase. jetBlue, for example, provides free internet access, so uptake rates by passengers are high.

"We analyse demand and traffic data and statistics so that can satisfy the SLA," says Buchman. "ViaSat uniquely provides a SLA that contains certain conditions, such as speed and availability. We offer an average of 10Mbps per seat 50% of the time, and an average of 3Mbps per seat 90% of the time. We can offer these rates at economic rates, and believe this is because we sell capacity from our high output satellites, rather than leasing the capacity at a fixed price." AC