

Global IP Network Mobility using Border Gateway Protocol (BGP)

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ABSTRACT

Connexion by Boeing provides real-time, high-speed Internet access to air travelers in flight and to other mobile platforms such as maritime vessels. Connexion by Boeing has implemented a unique method to allow global Internet Protocol (IP) network mobility for these mobile platforms using the Border Gateway Protocol (BGP).

This paper describes the implementation of the mobility method used for commercial aircraft and the mobility variations which have been deployed to support maritime vessels and small executive aircraft. The paper also looks at the methodologies used to derive Connexion by Boeing's current implementations of routing mobility. The current limitations of this implementation are explored along with current standards work and possible future optimizations based on the current deployment.

1. INTRODUCTION

Connexion by Boeing¹ provides Internet access to mobile platforms, including the support for Virtual Private Network (VPN) connections. Users also have access to IP-based television from rebroadcast live news and sports entertainment delivered via IP multicast. Each commercial aircraft equipped with the Internet service offers either an Ethernet Local Area Network (LAN) connection or a wireless 802.11a/b/g "WiFi" network connection, or both.

First, we examine the implementation of the IP mobility architecture which has been primarily designed for commercial aircraft.

2. NETWORK ARCHITECTURE

The Connexion by Boeing IP network, as shown in Figure 1 consists of the following network segments:

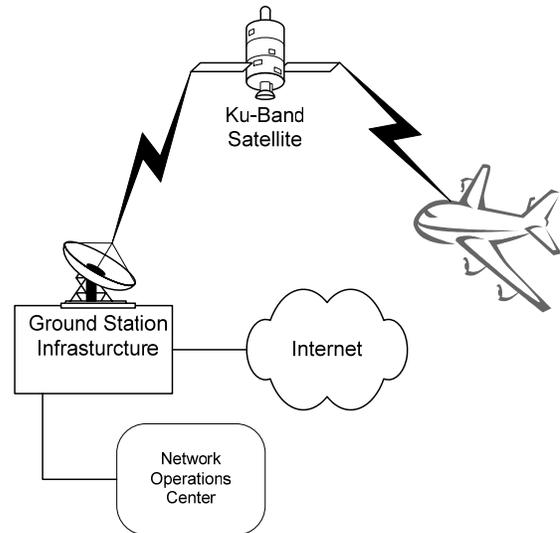


Figure 1: Overview of Network Architecture

- Airborne Network and its components
- Ku-band satellites, Satcom modems, and corresponding transmission and receiving equipment
- Terrestrial network gateways (i.e. "Ground Stations") which host command and control functions and network services
- Global terrestrial Wide Area Network (WAN) via the Internet which supports management and monitoring
- Network Operations Center which provides central management functions and support facilities to manage the global network

2.1. Airborne Network

The airborne network primarily consists of a set of wireless 802.11 access points, a CoreNetwork box, the Data Transmitter and Receiver (DTR), and a Ku-Band antenna mounted externally on the top of the aircraft. The CoreNetwork box provides onboard IP services such as DNS, DHCP, and a local HTTP Web

portal. The CoreNetwork also includes a Fast Ethernet switch to connect the wired and wireless distribution hardware in the cabin. The DTR consists of an IP router, network control processor, and Satellite Communications (Satcom) receive and transmission modems.

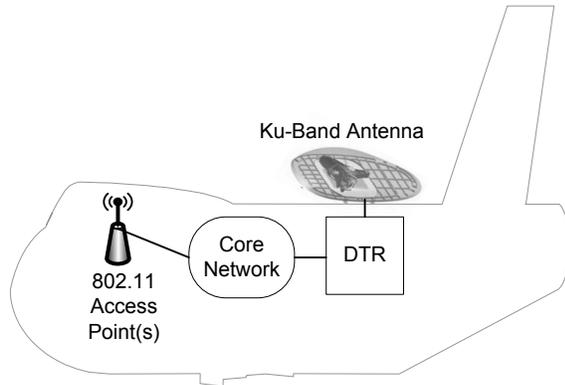


Figure 2: Airborne Network Components

The IP addressing scheme used on commercial aircraft is based upon the Aeronautical Radio, Incorporated (ARINC) 664 standard. The ARINC Airlines Electronic Engineering Committee (AEEC)² is an international standards group which is composed of airplane manufacturers, airlines, and other aviation equipment suppliers. The ARINC 664, Part 4 standard requires the use of RFC 1918³ private address space within the airborne network. The DTR applies one-to-one Network Address Translation (NAT)⁴ to packets when they leave or enter the aircraft network to meet the ARINC specification.

2.2. Satellite Communications

The Satcom infrastructure is based upon Ku-band satellites and CDMA technology and is implemented using modems manufactured by ViaSat. The Satcom link is composed of two simplex data links. A ground-to-air link, i.e. “forward-link”, is a broadcast link where all platforms operating within a specific transponder region receive all packets sent from the ground. Packets received at the mobile platform that are not destined to that specific mobile platform are dropped. The air-to-ground link, i.e. “return-link,” is created when a specific data-link channel is established for each mobile platform over a shared transponder. The return-link data rate is variable based upon the traffic rate needed by onboard users and is adjusted dynamically for each platform using a customized internally developed bandwidth allocation algorithm known as “Bandwidth on Demand” (BOD). The BOD algorithm attempts to

minimize the return-link data rate to ensure regulatory compliance with national⁵ and international⁶ satellite communications regulations and to provide adequate bandwidth to aircraft which are currently transmitting data.

2.3. Terrestrial Network

Ground stations consist of the Satcom Ground Receive and Transmit System (GRTS) plus supporting servers and IP routers/switches which provide data transport between the satellites and the Internet. Connexion by Boeing has deployed five geographically distributed ground stations around the globe. These five geographically distributed ground stations allow communications with a large majority of geosynchronous Ku-Band satellites.

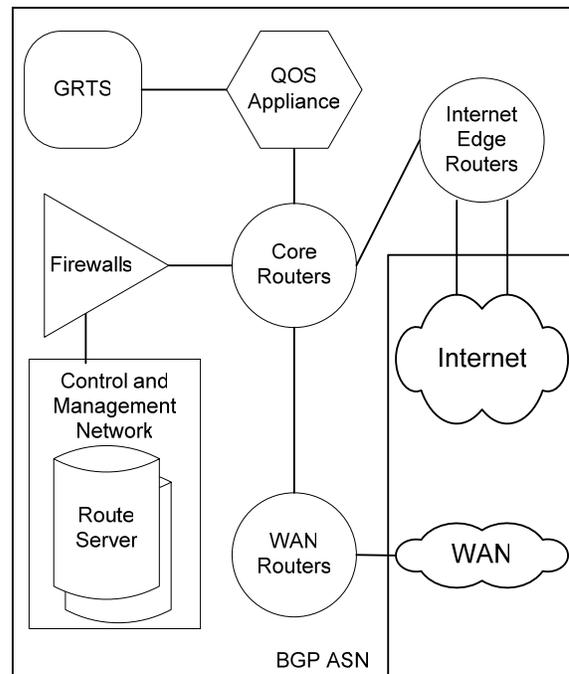


Figure 3: Ground Station Network Components

Each ground station is provisioned with upstream transit IP service from two different Internet Service Providers. Additionally, each Ground Station operates under a unique BGP autonomous system number (ASN).

3. MOBILITY REQUIREMENTS

Connexion by Boeing’s mobility requirements are driven by the desire to provide users continuous service throughout a flight. Our mobility requirements are unique compared with the focus of

most mobility implementations to date. Transcontinental jet aircraft have the capability of covering half the globe over the span of hours. A typical flight from Asia to Europe will use three different ground stations and four distinct transponders within half a day. The hosts, which could number in the hundreds, remain static with regard to the network. Most current mobility implementations, such as 802.11r roaming or MobileIP (RFC 3344)⁷, concentrate on providing service where the hosts are mobile compared to the network.

3.1. Service Trial

Static homing was the first methodology that was tested and implemented during the 2003 service trial with British Airways and Lufthansa Airlines. This mobility method required all the traffic to be backhauled to a single ingress and egress point to the Internet. The trial was conducted using two 747 aircraft operating between North America and Europe. Two separate ground stations were used to provide the trial service, one in Europe and one in North America. A third data center, located in North America, functioned as a network operations and management location and provided connectivity for both test platforms to the Internet.

This trial required all network traffic, even traffic that originated over Europe, to be backhauled over WAN circuits to Seattle, Washington, USA. Backhauling and tunneling solutions require the provisioning of a substantial global IP backbone to carry the backhauled traffic. These additional monthly recurring WAN costs would be substantial and were to be avoided, if possible.

Operating in a geosynchronous satellite environment adds approximately 600ms of round-trip latency for the ground station to aircraft transmission. This latency may have a dramatic effect on the user experience, especially with latency sensitive protocols such as TCP. In general, it is desirable for traffic flows to follow geography, as much as possible, to avoid excess latency.

3.2. Service Trial Findings

To provide the users with a consistent and stable network experience throughout the flight, there was a strong desire to have seamless connectivity including the transitions between satellites and ground stations. Seamless connectivity required the use of a mobility method that didn't break long-lived TCP sessions or

VPNs when a handoff occurred. The service trial also pointed out the effect of latency on specific applications. When excess latency is limited the user has a better overall experience.

Any proposed mobility solution needed to leverage existing routing technology, couldn't require outside networks to make changes to accommodate our mobile platforms and needed to be acceptable to network operators worldwide.

The increased WAN costs and the additional latency that would be incurred due to backhauling were the primary motivators to develop a more efficient mobility method. The overall desire was to find an optimal way to route traffic, reduce latency, improve network reliability, and allow for global connectivity throughout a flight.

4. BGP AS A MOBILITY PROTOCOL

Each aircraft is assigned a public IP address block which has been allocated by one of the Regional Internet Registries. Connexion by Boeing currently obtains IP address space from three registries: ARIN⁸, RIPE⁹, and APNIC¹⁰. In general, we address aircraft by region according to the home country of the airline. For example: Singapore Airlines aircraft are addressed from the APNIC allocations and SAS aircraft are addressed from the RIPE allocations.

Connexion by Boeing publishes its routing policy and route records in the Routing Assets Database (RADB) routing registry,¹¹ operated by Merit, to facilitate filtering by ISPs throughout the Internet.

4.1. BGP Route Announcement

Aircraft are assigned a /24 network to allow for the mobility of the aircraft to be seen throughout the global default free zone. The BGP routers throughout the core of the Internet do not rely on the use of a default route to find the next hop for a specific packet. These default free zone routers require a route for each prefix that is in use on the Internet. A /24 network is currently a commonly accepted filtering boundary for default free zone BGP routers. Prefixes smaller than /24, such as a /25, are filtered by most network operators at peering or transit exchanges.

As illustrated in Figure 4, when an aircraft is in two-way communications with a ground station (ASN "A") its public IP address block is announced via BGP to the upstream transit providers of the ground station. The aircraft's route is announced only from this ground station for the duration of the time the aircraft is being served from this ground station.

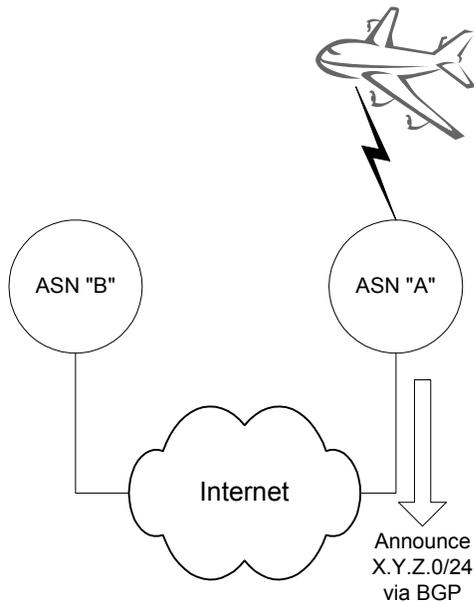


Figure 4: Aircraft operating from ASN "A" and associated BGP announcement

4.2. Routing Handoff

When an aircraft is moving between ground stations and therefore between satellite coverage regions the public IP address block is withdrawn from the BGP table in ground station "A" and is then announced by the next ground station "B" that will provide service to the aircraft, as shown in Figure 5. This process is commonly called a "handoff." The handoff process between different satellites commonly occurs during the duration of most transcontinental flights. A handoff between satellites requires the satellite antenna to repoint to the new satellite, acquire the forward-link signal, and then establish a return-link data channel. Reestablishing 2-way communications from a handoff usually takes less than a minute to complete.

Most ground stations provide uplink-downlink service for multiple satellites and satellite transponders. When a handoff occurs between two different satellite transponders within the same ground station the BGP routes will be updated

internally to the ground station only. No external change is propagated to the upstream BGP transit providers.

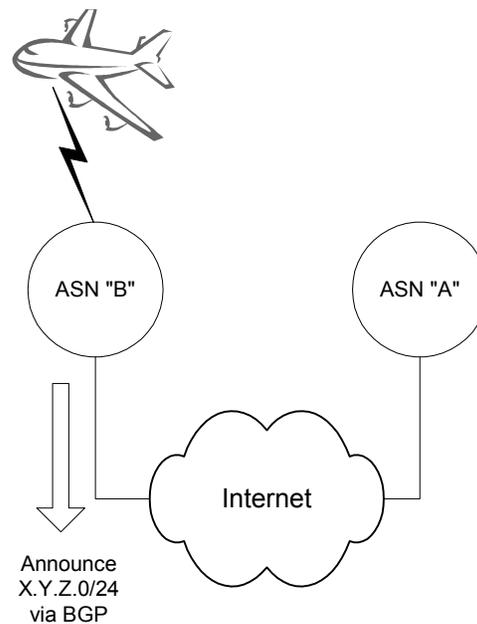


Figure 5: Aircraft operating from ASN "B" and associated BGP announcement after a handoff from ASN "A"

4.3. Announcement Propagation

Connexion by Boeing has deployed BGP route-servers in each of our ground stations to facilitate the selective announcement and withdrawal of BGP routes to provide mobility. A pair of route-servers communicates to the ground station BGP route-reflectors via internal BGP (iBGP). The routes announced by the route-servers are then propagated by the route-reflectors to other BGP speakers in the ground station and also to the upstream transit IP providers by external BGP (eBGP).

Each pair of BGP route-servers is located in a unique BGP ASN which corresponds to the ASN assigned to a ground station. This causes the public IP blocks assigned to the aircraft to change autonomous system numbers when the aircraft complete a handoff between ground stations. To date, no known operational effects have been noted from the announcement of these address blocks from different ASNs.

4.4. BGP Security Enhancements

It is understood, that future BGP protocol security enhancements, such as sBGP¹² or soBGP¹³, will likely require adjustments in the current implementation. The “inconsistent AS” can be removed from mobile platform routes by creating a “mobility ASN.” This mobility ASN would then contain only the route-servers which announce the mobile platform routes. This is easily accomplished by converting the existing route-servers internal BGP relationships to external BGP relationships.

When the existing iBGP neighbors are converted to eBGP neighbors the routing policies must be modified to insure similar behavior occurs. The current implementation uses changes to the next-hop attribute to direct traffic to the correct satellite modem for transmission to the aircraft. The next-hop attribute is handled differently by eBGP and iBGP. In eBGP, the next-hop attribute is explicitly reset to the IP address of the eBGP neighbor. In iBGP, the next-hop attribute is not modified.

To accomplish the same behavior of the routing policy between the route-server and its eBGP neighbor, the ground station route-reflectors in our design will need to be modified. First, the route-server will need to tag routes for a specific satellite modem with a unique community. Second, the route reflectors would need to translate this community tag to the next-hop associated with the satellite modem and modify the BGP announcement before propagating it to other BGP speakers within the ground station.

5. BGP MOBILITY ISSUES

During the initial design phase of the mobility architecture for commercial aircraft, there were concerns that the /24 networks would be filtered and/or dampened by a number of network operators worldwide. There were also concerns that the BGP reconvergence time would be too long and would leave the end user without connectivity for longer than desirable.

5.1. Route Acceptance/Dampening

A test was conducted by injecting and withdrawing a /24 network from the test ground station in Kent, Washington, US and the ground station which was used for the 2003 Connexion by Boeing in-service trial in Switzerland. The routes were announced and withdrawn in a manner similar to the method that was being proposed for commercial service. Connectivity

to the /24 network was tested by measuring the packet loss to a number of known globally dispersed Web sites. In general, most Web sites were reachable with only the /24 network being announced.

Testing of route propagation found that most providers will accept and propagate a /24 announcements. In the event, that some providers do not accept a /24 announcements, Connexion by Boeing is advertising a larger aggregate containing all of the mobile platforms routes. This larger aggregate will allow routing for all the mobile platforms even if end sites decide to filter the /24 announcements. For the BGP mobility method to be successful, all of our Internet providers must only exchange our routes amongst themselves. The mobile platform routes could be filtered at the edge of the Internet without a loss of connectivity to the mobile platforms. In many cases the filtering of these routes will not substantially alter the traffic path for networks that are well connected to Connexion by Boeing’s Internet providers.

The tests also observed no dampening effects for a normal handoff interval, usually 4-8 hours for an average flight. Dampening effects appeared only when repeated route announcements and withdrawals occurred within a short period of time, for example less than 5 minutes. Various papers¹⁴ have also explored the effects of BGP dampening on routing reachability and stability and have noted that the default values¹⁵ originally thought to be optimal may actually have a detrimental effect to the end user. These discoveries and the lack of CPU limited route-processors have possibly reduced the deployment of dampening in networks over time.

5.2. Route Reconvergence

The initial routing tests also measured the reconvergence time for the route announcements. The reconvergence time was acceptable given the Satcom handoff time. A number of different papers (“An Experimental Study of Internet Routing Convergence”¹⁶ and “An Analysis of BGP Convergence Properties”¹⁷) have reported that BGP convergence times within the global Internet were longer than anticipated. We have examined the BGP data captured by the Route Views Project¹⁸ and the RIPE RIS Collectors¹⁹ for mobile platforms using BGP to provide mobility and have anecdotally noted that most of the ASNs which constitute the major backbones of the Internet reconverge within about one minute for most handoffs. Some smaller outlying networks may not reconverge until 30-60 minutes after the handoff; it is believed that these

long reconvergence times are due to upstream networks dampening routes for the outlying networks. After the dampening is released another reconvergence cycle occurs.

A thorough analysis of this data has not been conducted at this time, however operational experience has shown that a large majority of the users of the Connexion by Boeing system do not notice the handoff, and established VPN sessions will remain established through a Satcom handoff and the BGP reconvergence period.

Connexion by Boeing is aware of the concerns the operator community has expressed in the past regarding excess route announcements and excess route updates. The current mobility method is not an optimal solution to limit route table entries or reduce route table updates.

Alternate methods could reduce route table updates while preserving the routing optimization currently available using the /24 announcements in BGP. Connexion by Boeing could create a peering and tunneling architecture that would provide “entry” points to the Connexion by Boeing network at specific well connected Internet locations. These peering locations would then tunnel traffic over Internet connections to the ground station currently serving the mobile platform. Another alternative would be to allow asymmetric routing between ground stations, although this method would likely require substantial additional cost for WAN infrastructure between ground stations. Data destined to the Internet from a mobile platform would exit at the local ground station and traffic returning to the ground station would go to the closest ground station, from a BGP routing table perspective. Traffic received by a remote ground station would then be forwarded on the global Connexion by Boeing WAN infrastructure. Other methods for global mobility are not well known at the time.

At the current time, the number of BGP route updates that are generated by the periodic injection and withdrawal of /24 route announcements is small compared with the total number of BGP updates generated by the routing system as a whole.

6. MOBILITY STANDARDS

Most of the work on IP mobility standards has focused on the implementations under IPv6, with the exception of basic IPv4 host mobility. Also, a majority of the early mobility work focused on host

mobility which does not provide any optimal solutions for our mobile networks.

The NEMO²⁰ working group has defined a set of basic protocols which allow for network mobility. However, these protocols rely heavily on the use of tunneling. The extensive use of tunneling does not provide for intuitive routing over large geographical areas such as the distances jet aircraft can fly in a single day.

The latency incurred due to tunneling between continents can be substantial.

Example #1: Latency with an aircraft’s home agent in Europe currently operating east-Asia to an Asia Web site.

Latency (ms)	
320	Aircraft to geo-synchronous satellite to ground East Asia
130	Asia to North America
70	East across North America
80	North America to Europe
80	Europe to North America
70	West across North America
130	North America to Asia
30	Within Asia
890 ms	Total One-Way Latency

Example #2: Latency with an aircraft dynamically homed in Asia to an Asian Web site.

Latency (ms)	
320	Aircraft to geo-synchronous satellite to ground East Asia
40	Within Asia
380 ms	Total One-Way Latency

Here we can see the substantial latency penalty that can be incurred due to IP tunneling required by the mobility protocol. In these two examples, we could reduce the time for a 3-way TCP handshake from approximately 2.7 seconds to about 1.1 seconds by eliminating the excess tunneling. The use of dynamic homing in this case substantially reduces the time required to establish a TCP connection. Extensive tunneling also requires the provisioning of additional bandwidth just to carry backhaul traffic. In certain regions, procuring this additional transit bandwidth can be very costly.

Some recent drafts, such as draft-thubert-nemo-global-haha-00.txt²¹, have tried to address the tunneling issues, but these drafts have not yet gained wide acceptance by the IETF community. These

Home-Agent to Home-Agent optimization drafts only address optimization within an autonomous system. True global mobility between autonomous systems requires the full operational support of a majority of network operators. This type of cooperation, while possible, would require the creation of “mobility agreements” to provide for traffic exchange between providers. These agreements would likely be similar to the peering agreements in place today between Internet service providers. Widespread acceptance of these arrangements and interoperability between global network operators is a huge barrier to entry for a global mobility solution based upon global HomeAgent to HomeAgent optimization.

7. MARITIME AND SMALL AIRCRAFT MOBILITY

Each type of mobile platform has a unique set of operating requirements. Connexion by Boeing evaluates those requirements when selecting the mobility method for the platform.

7.1. Executive Aircraft

Small or executive aircraft often have only a few passengers and shorter flights. These types of aircraft also operate primarily within a single region. These two operating factors and the lack of requirements for seamless handoff lead to a mobility method based upon Network Address Translation²², “NAT Mobility”.

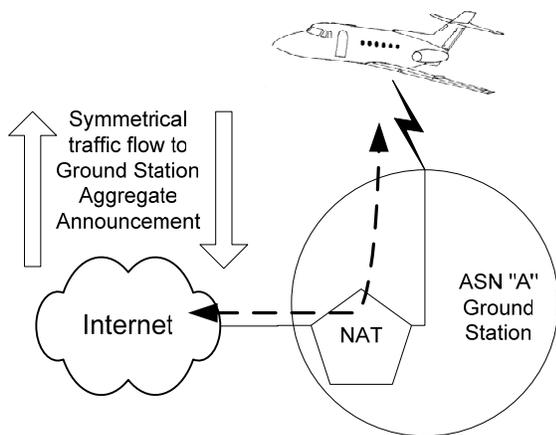


Figure 6: Executive Aircraft operations showing ground based “NAT Mobility”

This mobility method is provisioned using RFC 1918 address space on the mobile platform and assigned to the end hosts. NAT is then performed on mobile platform data traffic as it leaves the Ground Station.

Traffic using this method will always return to a single ground station because the NAT address blocks are announced only out of one ground station and NAT requires a symmetric data path. Aircraft using this mobility method will not be able to retain state between a ground station hand off and all long lived IP sessions will break.

7.2. Maritime Vessels

The maritime market is also a truly global market similar to commercial aircraft but with one large difference, speed. While a typical commercial aircraft could cross the Atlantic Ocean within six hours, a maritime vessel would make the crossing in around 8-10 days depending on weather conditions. The difference in speed and other operating factors lead to the design of a hybrid mobility method.

Connexion by Boeing’s maritime platform is provisioned with two separated LANs, a “UserLAN” and a “ServerLAN.”

The UserLAN, uses the “NAT Mobility” method that is also used by Executive aircraft. The users on this LAN have outbound access to the Internet. Since the time between a Satcom handoff is long there is little need to provide for seamless mobility. A handoff is unlikely to occur with a frequency that would cause user operability issues.

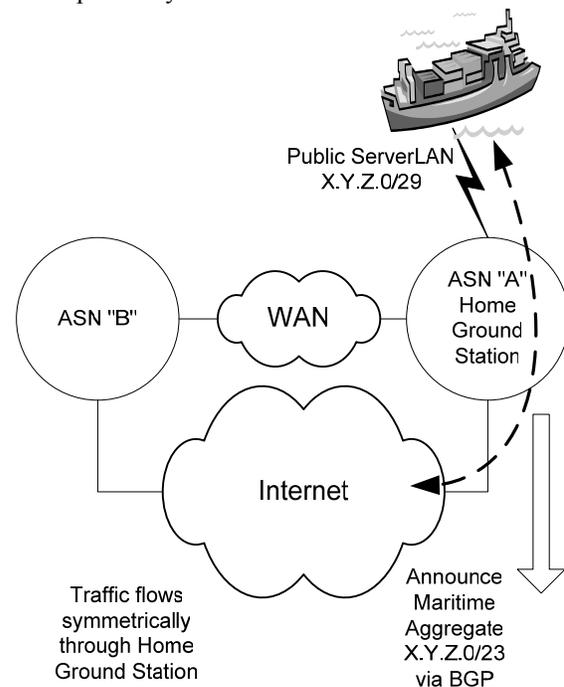


Figure 7: Maritime ServerLAN operation from Home Ground Station

The ServerLAN provides mobility using a public addresses block assigned to the vessel. This server LAN requires seamless mobility between ground stations and inbound access from the Internet to the vessel.

A small public address block is assigned to each vessel. The current default provisioning size is /29. This smaller block size was chosen to meet the needs of the maritime customers while being mindful of the limited availability of IPv4 address resources. Under existing IPv4 address policy it would be hard for Connexion by Boeing to justify the use of a larger “routable” public IP address block (/24) to the regional Internet registries due to the small number of users/servers that would be located on this LAN.

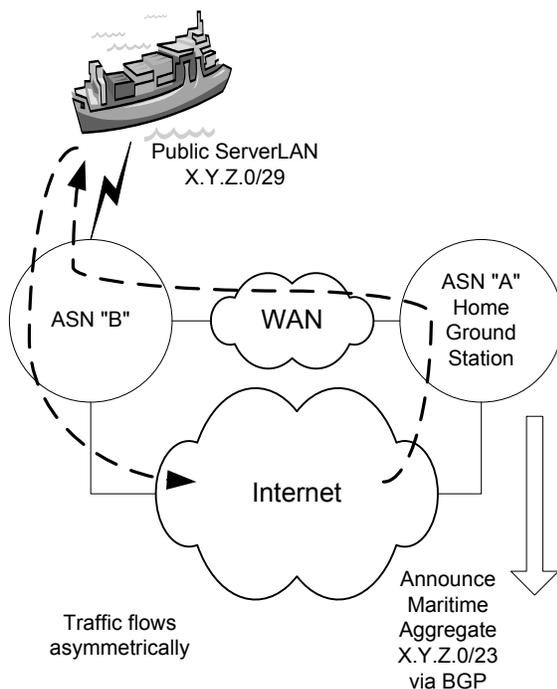


Figure 8: Maritime ServerLAN operation from Foreign Ground Station

This address block is then announced in BGP using our route servers in the same manner that is used for commercial aircraft. These routes, however, are not propagated to our upstream transit ISPs. Data from the server LAN is sent to the Internet from the ground station where the vessel is currently operating. Data from the Internet is sent back to the vessel via the vessel’s “home ground station.” A home ground station is statically defined for a group

of vessels. The home ground station announces, via BGP, a larger aggregate announcement, such as a /23. This aggregate announcement provides return routing for all the vessels which are served by the home ground station. This mobility method often increases the latency for the traffic on the path from the Internet to the vessel, but this latency was deemed to be acceptable for services operating on the maritime platforms.

8. FUTURE ENHANCEMENTS

The existing method to announce a unique BGP prefix for each platform can be optimized in the future using a number of different methods.

8.1. Regional Mobile Aggregation

Some aircraft usually operate within a specific region. These aircraft could be aggregated into a single IP address block and their individual announcements could then be withdrawn from the default free zone. If an aircraft from this block did move outside its normal operational ground station it could still be provided IP mobility by only announcing the address space for that specific aircraft.

8.2. Dynamic Network Assignment

A dynamic network allocation protocol could be developed to assign address space to a mobile platform on an as-needed basis. This would allow for the more efficient use of address space by allowing an aircraft which is not currently operating to release its address space for use by another for the duration of its next flight.

8.3. Mobile Prefix Communities

A unique community could be attached to the mobility routes which would allow service providers to filter these routes if they desired. RFC 1997²³ defines a set of unique globally defined communities, such as no-export, which can be used by providers to manipulate their routing tables. The addition of a new “mobile prefix” community could be used allow edge providers to automatically drop these redundant routes. This type of technique could also be used to mark routes that are inserted into the default free zone for load balancing. Unfortunately, all BGP communities are non-transitive and could be dropped or stripped by an upstream provider.

9. CONCLUSIONS

The use of BGP as a mobility method has been proven through the implementation within the Connexion by Boeing network. This solution provides a global IP mobility solution that does not require the use of special IP stacks on hosts. VPNs and other long-lived TCP sessions can be maintained across satellite transponder handoffs. This implementation does not require any special hardware or software on the airborne network. The implementation also does not require any special operational support from upstream transit providers or peers and it also does not require any special treatment of the mobile platform's BGP announcements. Long term concerns about the stability of this implementation due to the extra routes and corresponding updates which occur several times per day for active aircraft still need further study and examination.

10. ACKNOWLEDGEMENTS

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Connexion by Boeing would also like to thank ISPs and other individuals throughout the operator community who contributed to the success of bringing real-time Internet access to commercial aircraft.

11. REFERENCES

¹ Connexion by Boeing – <http://www.connexionbyboeing.com>

² ARINC AEEC Committee – <http://www.arinc.com/aeec/>

³ RFC 1918 (Address Allocation for Private Internets) – <http://www.ietf.org/rfc/rfc1918.txt>

⁴ A Look Inside Network Address Translators – http://www.cisco.com/web/about/ac123/ac147/archived_issues/ipj_7-3/anatomy.html

⁵ Connexion by Boeing Receives World's First FAA Certification for Onboard Broadband Information System – http://www.boeing.com/connexion/news/2002/q2/nr_020507j.html

⁶ Connexion by Boeing Receives Boost from International Telecommunications Union Approval of Global Spectrum Allocation – http://www.boeing.com/connexion/news/2003/q3/nr_030707j.html

⁷ RFC 3344 (IP Mobility Support for IPv4) – <http://www.ietf.org/rfc/rfc3344.txt>

⁸ American Registry for Internet Numbers (ARIN) – <http://www.arin.net>

⁹ RIPE NCC – <http://www.ripe.net>

¹⁰ Asia Pacific Network Information Centre (APNIC) – <http://www.apnic.net>

¹¹ RADB – <http://www.radb.net>

¹² Secure BGP (sBGP) – <http://www.ir.bbn.com/projects/s-bgp/>

¹³ Secure-Origin BGP (soBGP) - http://www.cisco.com/web/about/ac123/ac147/ac174/ac236/about_cisco_ipj_archive_article09186a00801c_5a9b.html

¹⁴ Route flap damping: “harmful”? – <http://www.nanog.org/mtg-0210/flap.html>

¹⁵ RIPE Routing-WG Recommendations for Coordinated Route-flap Damping Parameters – <http://www.ripe.net/ripe/docs/routeflap-damping.html>

¹⁶ An Experimental Study of Internet Routing Convergence – http://research.microsoft.com/scripts/pubs/view.asp?TR_ID=MSR-TR-2000-08

¹⁷ An Analysis of BGP Convergence Properties – <http://www.acm.org/sigs/sigcomm/sigcomm99/papers/session8-1.html>

¹⁸ Route-views – <http://www.routeviews.org/>

¹⁹ RIPE Routing Information Service – <http://www.ripe.net/projects/ris/>

²⁰ IETF Network Mobility Working Group - <http://www.ietf.org/html.charters/nemo-charter.html>

²¹ Global HA to HA protocol - <http://mobilenetworks.org/nemo/drafts/draft-thubert-nemo-global-haha-01.txt>

²² RFC 1631 (IP Network Address Translators) - www.ietf.org/rfc/rfc1631.txt

²³ RFC 1997 (BGP Communities Attribute) - <http://www.ietf.org/rfc/rfc1997.txt>