Requirements for Communication Systems in Future Passenger Air Transportation

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Agenda

- Passenger Air Transportation
- Communications in Passenger Air Transportation
- Current scenario
- Capacity requirements
- Multimode operation approach
- Conclusion
- References
Passenger Air Transportation

Objective

- Offer a fast and secure transport of passenger from one place to another place.
Passenger Air Transportation

Commercial aviation forecast

- Passengers/year: 5 billion ➔ 12 billion by 2031
- Aircraft movements/year: 77 million ➔ nearly double by 2031

Source: Boeing, 2013
In-flight entertainment (IFE)

- 1921 – The First in-flight movie (Aeromarine Airways)
- 1932 – The first in-flight television called “media event” (Western Air Express)
- 1935 – Atari video games were introduced on-board flights (Braniff International Airways)
- 1936 – Piano, lounge, dining room, smoking room, and bar (Airship Hindenburg)
- 1937 – The first recorded A/G radiotelephone service on a scheduled flight (Northwestern Airlines)
- 1963 – The first pneumatic headset used on board (AVID Airline Products)
- 1979 – Pneumatic headsets were replaced by electronic headsets
- 1982 – The moving-map system information (ASINC, Inc.)
- 1985 – The first audio player system based Tape Cassette technology
- …
In recent years, IFE has been expanded to include in-flight connectivity.

**In-flight entertainment and connectivity (IFEC)**

- 2000 – High-speed connectivity to commercial aviation (Boeing)
  - Satellite telephony
  - In-flight broadcast
  - Data Communication
  - Wi-Fi
  - GSM Network
  - …
Communications in Passenger Air Transportation

"Sky-to-Earth Phone Service Offered On Air Liner"
Popular Mechanics, September 1937

1. Infotainment
2. Office (in-flight)
3. Telemedicine
4. Flight security
5. Logistic & maintenance
Current scenario

Aeronautical Telecommunication Network (ATN)

- At the present time, a typical scenario in aeronautical communications is the ATN and sub-network
- ATN and sub-networks are operated between three principal segments
- These sub-networks include enhanced SatCom networks, CPDLC, FANS, ADS-C, AIRCOM, etc.
Current scenario

- Increase in supply and demand of passenger air transportation market, forces airlines to offer more and more onboard and in-flight services

Overall end-to-end system architecture for A/G broadband and SatCom
The estimation of future capacity requirements for a single A/C is based on the ETSI packet model for Internet traffic

\( N_{pc} \): mean number of pages per session,

\( D_{pc} \): interarrival time between web pages,

\( N_d \): mean packet number of packets per page,

\( D_d \): mean value of gap time between two consecutive packets

\( T_{SON} \): session active time

\( T_{SOFF} \): session inactive time.

Size of each packet.
Capacity requirements

Another important factor into consideration is $S_d$, which stands for the size of each packet (datagram).

$$S_d = \min (P, m)$$

Where $P$ is normal Pareto distributed random variable ($\alpha=1.1$, $k=81.5$ bytes) and $m$ is maximum allowed packet size, $m=66,666$ bytes. The probability density function of the datagram becomes:

$$f_n(x) = \begin{cases} \frac{\alpha k^\alpha}{x^{\alpha+1}}, & k \leq x < m \\ \beta, & x = m \end{cases}$$

Where $\beta$ is the probability that $S_d > m$:

$$\beta = \int_{m}^{\infty} f_n(x) dx = \left(\frac{k}{m}\right)^{\alpha}, \alpha > 1$$
Then the mean packet size can be calculated as:

$$
\mu_n = \int_{-\infty}^{\infty} x f_n(x) \, dx = \int_{k}^{m} x \, \frac{\alpha k^\alpha}{x^{\alpha+1}} \, dx + m \left( \frac{k}{m} \right)^\alpha = \frac{\alpha k - m \left( \frac{k}{m} \right)^\alpha}{\alpha - 1}
$$

With the parameters above the average size is:

$$
\mu_n = 480 \, \text{bytes}
$$

Today’s average web page has surpassed the 1.5 MB mark, arriving to 1.71 MB in February 2014. At this rate (average increase of 32% per year), the average page size will reach 8 or 9 MB by 2020.
Capacity requirements

Therefore, we can use these values to the mean input rate during an active session \( (R_s) \) as follows:

With the parameters above, the average size is:

\[
R_s = \frac{N_{pc} N_d \mu_n}{N_{pc} D_{pc}} = 349,515 \text{ bps}
\]

<table>
<thead>
<tr>
<th>A/C</th>
<th>Number of passengers</th>
<th>Minimum expected mean data rate (Mbps)</th>
<th>Minimum expected mean data rate (MB)</th>
<th>Maximum expected mean data rate (Mbps)</th>
<th>Maximum expected mean data rate (MB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A320</td>
<td>150 - 180</td>
<td>52.43</td>
<td>6.55</td>
<td>62.91</td>
<td>7.86</td>
</tr>
<tr>
<td>A330</td>
<td>253 - 440</td>
<td>88.43</td>
<td>11.05</td>
<td>153.79</td>
<td>19.22</td>
</tr>
<tr>
<td>A350</td>
<td>270 - 550</td>
<td>94.37</td>
<td>11.80</td>
<td>192.23</td>
<td>24.03</td>
</tr>
<tr>
<td>A380</td>
<td>555 - 853</td>
<td>193.98</td>
<td>24.25</td>
<td>298.14</td>
<td>37.27</td>
</tr>
<tr>
<td>B737</td>
<td>85 - 215</td>
<td>29.71</td>
<td>3.71</td>
<td>75.15</td>
<td>9.39</td>
</tr>
<tr>
<td>B777</td>
<td>301 – 550</td>
<td>105.20</td>
<td>13.15</td>
<td>192.23</td>
<td>24.03</td>
</tr>
<tr>
<td>B787</td>
<td>210 – 330</td>
<td>73.40</td>
<td>9.18</td>
<td>115.34</td>
<td>14.42</td>
</tr>
<tr>
<td>B747</td>
<td>467 - 605</td>
<td>163.22</td>
<td>20.40</td>
<td>211.46</td>
<td>26.43</td>
</tr>
</tbody>
</table>

Table 1. Number of passengers, minimum and maximum expected mean data rate per A/C type
Capacity requirements

• Another aspect to take into account is the evolution of ACARS.
• ACARS system is limited to 2.4 Kbps.
• At a higher data rate, communications will become impossible.
• To support ACARS traffic growth, the capacity constraints as well as the Air Traffic Services (ATS), the use of data link and A/C equipage with (Electronic Flight Bags/Electronic Log Books) EFB/ELB, ACARS will be replaced by AIRCOM by SITA.
• The key challenge to A/C transition from ACARS to new generation communications systems is the cost of modifying A/C systems.
• This practically means that A/C will continue to use ACARs until at least 2020 but will increasingly use other data communications links in parallel.
Capacity requirements

ATN: Aeronautical Telecom. Network
GEO: Geostationary Earth Orbit
GES: Ground Earth Station
IRD: Iridium Gateway & message Processor
LEO: Low Earth Orbit
RGS: Remote Ground Station
VGS: VHF Ground Station

AIRCOM Data Link System Architecture
Multimode operation approach

Providers of satellite networks are enormously orienting to utilize Ka-band for their next generation of satellites

Table 2. SatCom network providers’ features

<table>
<thead>
<tr>
<th>Orbit</th>
<th>Inmarsat</th>
<th>Iridium</th>
<th>ViaSat</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEO - Geostationary Earth Orbit (35,786 Km)</td>
<td>LEO- Low Earth Orbit (780 Km)</td>
<td>GEO - Geostationary Earth Orbit (35,786 Km)</td>
<td></td>
</tr>
<tr>
<td>Multiple-access scheme</td>
<td>FDMA / TDMA</td>
<td>FDMA / TDMA</td>
<td>MF-TDMA</td>
</tr>
<tr>
<td>Modulation types</td>
<td>O-QPSK / pi/4-QPSK / 16-QAM</td>
<td>QPSK / DE-QPSK / DE-BPSK</td>
<td>QPSK / 8-PSK / 16-APSK / 32-APSK</td>
</tr>
<tr>
<td>Latency</td>
<td>1.2 – 3.5 sec</td>
<td>427 ms – 1.7 sec</td>
<td>1.2 – 3.5 sec</td>
</tr>
<tr>
<td>Service link</td>
<td>L-Band / Ku-Band / Ka-Band (Global Xpress, 2014)</td>
<td>L-Band / Ka-Band (Iridium Next, 2015)</td>
<td>Ka-Band</td>
</tr>
<tr>
<td>Feeder links</td>
<td>C-Band / Ku-Band</td>
<td>Up: Ka-Band</td>
<td>Up: Ka-Band</td>
</tr>
<tr>
<td>Services</td>
<td>Voice / Fax / Low-speed and high-speed data / VoIP / Flight Tracking / Safety services</td>
<td>Voice / Fax / Low data / Flight Tracking / Safety services</td>
<td>Voice / Fax / Low-speed and high-speed data / VoIP</td>
</tr>
</tbody>
</table>
Multimode operation approach

- In this regard, Software Defined Radio (SDR) are an ideal platform for prototyping and evaluating airborne platforms.

- Software routines are perfectly suited for:
  - Switching to other wireless protocols,
  - Integrate new standards in A/Cs without substantial cost,
  - Developing monitoring tools to guarantee QoS, processing signals for more efficient use of spectrum, and
  - Ensuring the scalability and configurability of system
Multimode operation approach

Considering that in a near future the bulk of the satellite network will work in Ka-band, we can propose an approach using SDRs, cognitive techniques and collaborative avionic network

- Switch between different modulation types (Multi-modulation / Adaptive modulation).
- Switch between different SatCom networks (Reconfigurable).
- Demodulate the down converted signals (Reprogrammable).
- Simulate reception scenarios (Flight phases).
- Cognitive radio capabilities (Resource arbitration)
- Scalable design and implementation.
Multimode operation approach

Collaborative Avionic Network (CAN)

ATSC : Air Traffic Security Coordinator
APC : Airline Passenger Communications
AOC: ATN Operational Communications
ATN: Aeronautical Telecomm Network
A/A: Air-to-Air
A/G: Air-to-Ground
G/G: Ground-to-Ground
AMSS: Aeronautical Mobile Satellite Service
HFDL: High Frequency Data Link
VDL2/3/4: VHF data link mode 2/3/4

Communication link Aircraft-ATN A/G router via A/A router and A/A connection Flowchart
Multimode operation approach

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Conclusion

- We have presented minimum and maximum expected mean data rate per A/C type and the number of passengers for RCSFPAT.
- In future works, these values (29.71 – 300 Mbps) will be useful for design of avionics communication cognitive networks in terms of QoS, capacity and data rate.
- In response to the increase in air traffic volume (5% per year), operational efficiency and environmental issues as well as enhancing safety, we have presented a solution based on SDR multimode capable of complementing the services provided by SatCom network providers in Ka-Band.
References


