The Iridium Satellite Network

Simon Moorhead
Ericsson Australia and New Zealand

Abstract: An historic paper from 1991, republished here online, describes the features of the Iridium low earth orbit satellite system, which provided continuous line-of-sight coverage to any point on the earth's surface via L-Band mobile handsets.

Keywords: History, Telecommunications, Iridium, Satellite, Starlink

Introduction

The Iridium Satellite System was developed and patented by Motorola in the late 1980s and became operational in the late 1990s. It was designed to have a constellation of 77 satellites (77 being the atomic number of Iridium) orbiting in a low earth orbit (LEO) approximately 780 km above the earth's surface. The Iridium mobile handsets operated in the L-Band (1–2 GHz) and effectively provided continuous line-of-sight coverage to any point on the earth's surface.

The historic paper (McIntosh, 1991) describes the proposed Iridium satellite system before it was launched. A constellation of 11 satellites per plane and 7 polar orbits were required to provide continuous coverage. In the end, 66 satellites were deployed in 6 polar orbits to reduce the significant cost of deployment. Iridium utilised American, Russian and Chinese launch vehicles. According to Graham (2018), the total set-up cost for the first-generation fleet was around USD 5 Billion.

The satellites effectively created cellular-like coverage over the entire earth. They provided inter-satellite communications at 20–30 GHz and the same frequency was used for satellite-to-gateway communications. The inter-satellite links were dimensioned for 3,000 channels and the gateways for 2,000 channels. The historic paper provides details of the Iridium communications system, including its modulation schemes and proposed link budgets.

While the system was a technical success, it suffered from several practical drawbacks, which limited its commercial uptake. The handsets were bulky, and L-Band did not penetrate buildings very well. At the time, people were very familiar with the performance of analogue

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cellular phones and the Iridium handsets were considered inadequate by comparison. The post-launch airtime cost of around $10 per minute also dampened the market demand.

In 1999, Iridium went into Chapter 11 bankruptcy after falling short of revenue forecasts, but the company was never wound up. A number of changes were made to the company structure and, with American Government support, the system was eventually rescued. Through prudent management the Iridium system has survived, and the original satellites have been subsequently replaced and are back challenging traditional competitors like Inmarsat.

Fast forward to today and the Starlink LEO system from Elon Musk's SpaceX is the new broadband competitor to Iridium. Each Starlink end-user terminal is a satellite-fed, fixed broadband hotspot (Arevalo, 2020), rather than a true mobile service. With 1,900 satellites currently deployed and 12,000 proposed, it is easy to see that Starlink has considerably more capacity than Iridium.

In Australia, Starlink has a one-off set-up cost per user of around AUD 800 and Internet access costs around AUD 130 per month. Download speeds are up to 100 Megabits per second and upload speeds are up to 20 Megabits per second, with a latency of only 50 milliseconds. This contrasts with a latency of around 600 milliseconds for satellites in geostationary orbit and the reason LEO solutions are favoured for near-real-time satellite-to-ground communications, where lower latency is necessary.

Starlink uses SpaceX as its launch partner and currently has the capability to launch 60 satellites at a time. SpaceX are currently planning between 300 and 400 satellites per launch, using reusable first-stage rockets and are actively working to develop reusable second-stage rockets. This would mean that SpaceX would have a totally reusable launch vehicle that could deploy hundreds of satellites at a time, significantly lowering launch costs. It remains to be seen whether Starlink will be successful in the long term, but the larger capacity and reduced launch costs will certainly assist the business model to break even.

References

Arevalo, E. (2020). SpaceX's Starlink 'UFO on a stick' User Terminal Prototypes Revealed In Photos. Tesmanian, 19 June 2020. Available at https://www.tesmanian.com/blogs/tesmanian-blog/ufo-starlink-terminal

Graham, W. (2018). Iridium NEXT-5 satellites ride to orbit on SpaceX Falcon 9. NASA Spaceflight.com, 29 March 2018. Available at https://www.nasaspaceflight.com/2018/03/iridium-next-5-satellites-spacex-falcon-9/

McIntosh, G. R. (1991). Iridium — A Global Satellite Cellular Network, *Telecommunication Journal of Australia*, *41*(2), 63–66.

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The Historic Paper

Iridium — A Global Satellite Cellular Network

Glyn R. McIntosh, Telecom Australia

This paper provides an introduction into the technical concepts of the Iridium system. Iridium is the name of a proposed global satellite communications system capable of providing voice and data communications to small handheld terminals. The system operates via a constellation of low earth orbiting satellites circling the earth in North South planes at a height of 760 km.

Introduction

Iridium is the name that has been given to a new satellite based global communications system that is being developed by Motorola. Telecom is assessing the likely impact of Iridium and the possible role it may play in its implementation. The system will use a constellation of 77 small, smart satellites that are placed in a low earth orbit to provide continuous line-of-sight coverage to any point on the earth's surface. Iridium was chosen as the name for the system since the Iridium atom has 77 electrons encircling its nucleus. This constellation in conjunction with associated earth station gateways, that interface to the public switched network, will provide a packet switched digital communications system. Voice, data and paging services will be provided, with users able to communicate using small low-cost handheld transceivers similar to those currently in use with the existing Cellular Mobile Telephone System (CMTS). Dick Tracey communicator here we come.

In addition to the handheld terminals, mobile terminals may also be used on virtually any type of vehicle. Since the system will use a small omnidirectional antenna with low cost terminals the service will find application in many areas where it has not been possible to provide reliable communications in the past due to both economic and/or size limitations. Also since the satellites are in a polar orbit the service will be as good in the polar regions as it is at lower latitudes, whereas geostationary satellite systems have to tolerate inadequate polar coverage.

Motorola aims to develop a consortium of international companies to establish and operate the Iridium space segment, and a meeting of possible members was recently hosted by Motorola in Arizona. Telecom attended this meeting along with several international organisations.

Recently Motorola announced that Lockheed would be teaming with Motorola and that Lockheed would be responsible for the overall spacecraft design and manufacture. Hutchison Telecom was also reported recently in the press as intending to join the consortium.

Satellite Constellation

The constellation consist of 7 planes with 11 satellites in each plane circling the earth in the same direction in a polar orbit at a height of around 760 km. The separation between adjacent planes is approximately 27°, with the separation between planes 1 and 7 of about 17.7°. Satellites in adjacent planes are around 180° out of phase with minor corrections made to eliminate collisions at the poles. A schematic of the constellation is shown in Figure 1.

The satellites are small and relatively cheap ($25 — 30m in orbit) and will have a 5 — 8 year life. These satellites are suitable for use with a low cost launch vehicle such as the Pegasus. Such a low cost launch vehicle is required because to maintain the constellation after it is established, a replacement satellite will be launched on average every month.

The antenna system on each satellite is able to generate up to 37 spot beams and a 7 cell frequency reuse pattern is used to conserve spectrum in a similar fashion to CMTS. The 37 spot beams are projected onto the earth in a contiguous hexagonal pattern as indicated in Figure 2. Such a cell pattern is analogous to the cell pattern used for CMTS. The diameter of each cell at the surface of the earth is approximately 670 km, and as the satellites approach the poles the outer cells are progressively turned off in order to conserve power, and control interference with satellites in adjacent planes. Because these outer cells are progressively turned off only about 56% of Iridiums 2849 cells are on at the same time.

Currently Motorola and Lockheed are undertaking a detailed analysis of the satellite parameters in order to achieve the best compromise between system performance and satellite mass and cost. As a result of this analysis some of the parameters mentioned may change. These design changes would have some impact on the traffic capacity of the network however since the satellites only have a relatively short life it will be

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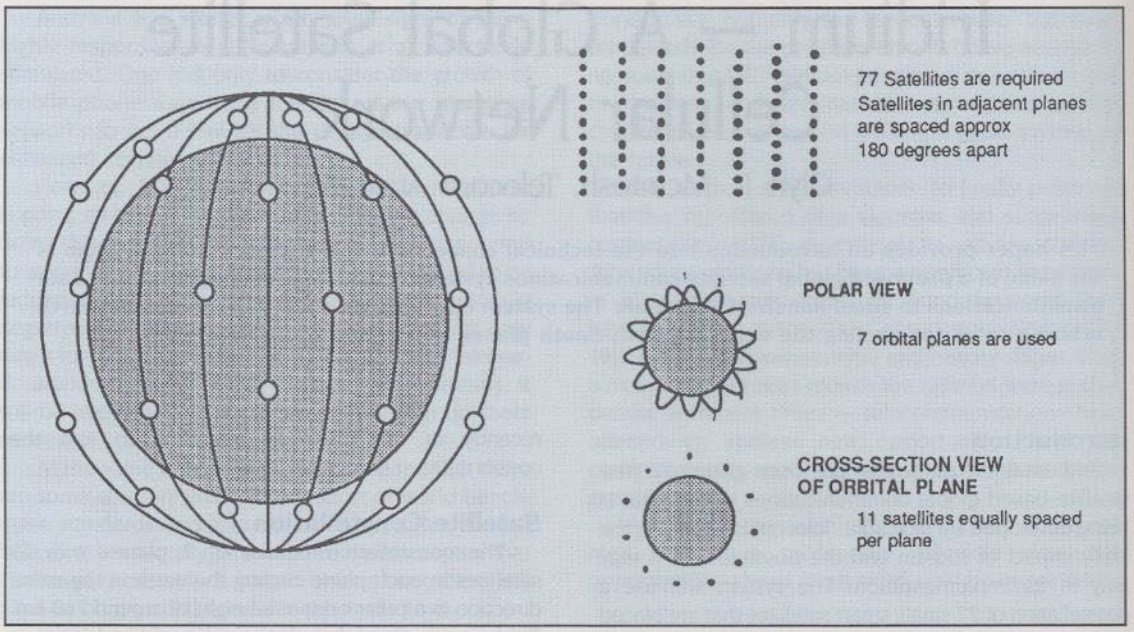

Figure 1: Satellite Constellation

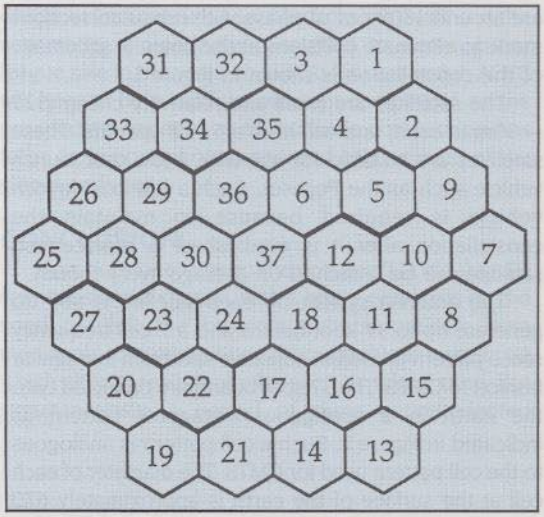

Figure 2 Satellite Antenna Spot Beam Pattern

possible to upgrade the network as technology improves.

Communications System

The cells formed by the satellite spot beam antennas travel across the surface of the earth at an approximate speed of 7400 metres per second, and the system provides automatic handover of calls between cells. Because of the high cell speed, users appear stationary on the earth with respect to the cell and this simplifies handover since the potential handover is typically to one of two cells and not one of six as in CMTS. Handovers will occur whether the user is moving or stationary and occur every 60-90 seconds.

Calls are routed from the user to the nearest satellite and then via inter-satellite links between adjacent satellites in the same plane and between satellites in adjacent orbital planes until the desired terrestrial gateway can be reached.

The key parameters of these communications links may be summarised:

Satellite / User

- QPSK modulation, packet format used with error detection and correction.
- multiple access format that uses both time division (TDMA) and frequency division (FDMA).
- transmission in band 1 GHz — 3 GHz.
- 2.2 : 1 digital speech interpolation (DSI) used.
- support voice operation on a circuit with a BER of 10−2.
- 12 dB margin allowed for shadow losses.

Satellite / Satellite

- High rate QPSK with TDMA/FDMA access control used for round the world transmission.
- Satellites communicate with the satellite that is leading and following in the same orbital plane and also with 2 satellites in each adjacent plane (4 cross-links per satellite).
- 20 and 30 GHz band is proposed.
- Capacity of each link is approximately 3000 channels.

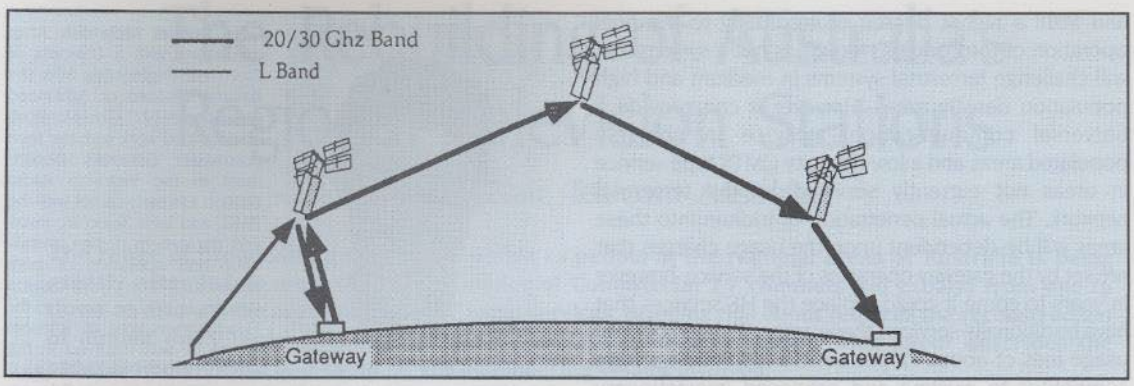

Figure 3: Typical Call Routing

- designed to support a BER of less than 10−7 using ½ rate FEC coding.

Satellite / Gateway

- Each satellite can communicate to the terrestrial network via a Gateway. Each gateway has steerable antennas for satellite tracking.
- 20 and 30 GHz band is proposed.
- High rate QPSK modulation with TDMA access control.
- Capacity of each link is approximately 2000 channels.
- The satellite/gateway link is also used for communications to the System Control Centres which control the allocations of channels between the user and the gateway and for general system housekeeping functions.
- designed to support a BER of less than 10−7 using ½ rate FEC coding.

Typical call routing is indicated in Figure 3 showing these three communications links.

Each gateway requires a minimum of two 3.3 metre tracking antennas separated by approximately 40 km in order to provide space diversity. Space diversity is necessary because propagation at 20/30 GHz is very dependent upon atmospheric conditions. In the initial system configuration 5-20 gateways will be provided, however the system can support up to 250 gateways. Access to the system will be co-ordinated via two System Control Centres which may be co-sited with gateway stations.

The final capacity of the system is related to the frequency spectrum that will be available for the user/satellite links. The preferred frequency band for these links is the L-Band (1500 MHz) and the demand of services using this band is already high. However an allocation of 20 MHz will provide a capacity of more than 300,000 simultaneous voice or data channels world-wide. This may seem like a large capacity however, it must be remembered that a large number of these channels will lie in sparsely populated areas where demand will be minimal. Also on average each individual cell will support just over 200 simultaneous calls. Since the cell diameter is about 670 km, Iridium is not, and cannot be used as a substitute for the terrestrial network in areas of medium or high density population. The cell diameter user for the initial implementation may also be larger than this initial design specification in order to meet satellite weight constraints.

Since the system relies solely on digital communications channels, voice will be digitised via an encoder into a 4.8 kbit/s data stream, and depending upon technology development at the time even 2.4 kbit/s encoding could be used. Data transmission at 2.4 kbit/s will also be supported with a ½rate Forward Error Correcting (FEC) code being provided within the system.

Implementation Timetable

The construction of the Iridium system is a massive project requiring a capital investment of more than $US2b for the space segment and the two system control centres. This capital requirement is spread over a period of several years. Satellite construction is due to commence in 1992, testing of the final service is expected to start in 1996 with services being provided during 1997. This timetable is very optimistic and delays of up to two years are quite feasible.

Summary

As can be seen Iridium is a very ambitious project requiring in excess of two billion dollars of capital investment. However Motorola are very keen to proceed with the service and have already filed a system application with the U.S. Federal Communications Commission. They have also been active in the international arena in relation to spectrum allocation and the development of a consortium to supply and operate the required space segment. Motorola's teaming arrangement with Lockheed to design and manufacture the satellite segment does indicate their high degree of commitment to the system

and instil a higher degree of credibility to the final operation of the concept. Iridium is not a system that will challenge terrestrial systems in medium and high population density areas. However it can provide a universal communications service in sparsely populated areas and a low capacity CMTS type service in areas not currently serviced by the terrestrial network. The actual penetration of Iridium into these areas will be dependent upon the usage charges that are set by the gateway operators of the service, however in years to come it could replace the HF services that have traditionally serviced these areas. With anticipated usage fees of about $2 per minute it will be a strong competitor to existing and proposed geostationary mobile satellite services such as INMARSAT and the local domestic MOBILESAT service being implemented by Aussat.

Glyn Robert McIntosh After graduating with a Diploma of Electronic Engineering from the Ballarat Institute of Advanced Education in 1971 Glyn McIntosh commenced work with the then Postmaster General's Department in the Victorian Radio Section. His early career with the PMG, and later Telecom, involved the system design, installation and operation of both radio and line transmission systems. In 1982 he moved to the Headquarters area of Telecom where he was involved in the introduction of display paging into the Telecom Telefinder network. In 1986 he moved to the Satellite Services Product Team in Telecom where he is now the Manager of the Project Management and Customer Consultancy Section.