Revolutionizing Low Earth Orbit Satellite Systems

White Paper 1

A Technical Deep Dive into Disruptive Satellite Communication

September 2024

STARMESH GLOBAL COMMUNICATIONS
Johns Creek, Georgia | Princeton, New Jersey | McHenry, Illinois

STARMESH™ - LEO SATELLITE SYSTEMS
Introducing StarMesh Global™ Satellite Communications

Many companies are pursuing global satellite communications, but traditional Low Earth Orbit (LEO) systems require significant investment to design, build, and launch hundreds of satellites to cover specific regions. Geostationary (GEO) and LEO systems rely on heavy, mechanically complex satellites that require extensive engineering, precision construction, costly launches, and sophisticated telemetry and software to maintain orbit. These high costs have limited participation in the field to those with access to substantial financial resources.

StarMesh Global is poised to revolutionize satellite communications by replacing these heavy, complex systems with lightweight, cost-effective satellites. StarMesh's patented technology eliminates the need for controlled orbital paths, altitudes, and orientations, drastically reducing design, build, launch, and operating costs to roughly 1% of traditional systems. This breakthrough will significantly lower the barrier to entry and disrupt the current industry model.

StarMesh Global has developed an extensive patent portfolio for stochastically distributed satellites that autonomously route data through the constellation. These satellites pair antennas and determine optimal routes based on radio parameters, such as signal-to-noise ratio, without centralized control or attitude adjustments (pitch, roll, and yaw).

This innovative approach relies on the statistical certainty that enough low-cost satellites can be placed in orbit to maintain constant communication between ground stations and satellites. This method contrasts sharply with conventional systems that depend on precise satellite positioning and pre-calculated routes.

This paper outlines the technical and commercial innovations behind StarMesh Global's patented approach and highlights the features that will disrupt the satellite communications industry.

I. Satellite Internet Today

Since 2015, engineers and scientists have been working to use satellites to provide global Internet access. Early efforts focused on bringing connectivity to the Equator, targeting remote areas, islands, and underdeveloped regions. These initiatives have attracted investments ranging from hundreds of millions to billions of dollars.

A key factor driving this industry is the significant reduction in the cost and weight of electronic components used in communication satellites. Lighter satellites reduce launch costs, and lower costs make these systems more viable. However, the most significant opportunity lies in creating systems with enough bandwidth to compete directly with terrestrial Internet, telephone networks, and streaming video services.

StarMesh Global has developed low-cost LEO satellite systems to achieve this goal while maintaining high-quality service, offering a competitive alternative to traditional networks.

II. STARMESH GLOBAL™—A New Approach

StarMesh Global, headquartered in Princeton, NJ, is pioneering a groundbreaking method for satellite-based communication by rethinking satellite design from the ground up.

The high cost of satellites remains one of the biggest barriers to advancing space-based communication systems. In 2020, the global revenue generated by satellite companies was estimated in the billions, but achieving that revenue required an investment of similar magnitude.

While these costs can be amortized over a satellite system's typical 10-15-year lifespan, they still demand significant upfront investment to design, build, launch, and maintain the satellites, replace malfunctioning units, and control their orbits and orientations.

StarMesh Global dramatically reduces these costs by eliminating unnecessary weight, components, and design complexity. Unlike traditional satellites, StarMesh Global satellites have no:

- Rocket thrusters
- Rocket fuel
- Solar sailing mechanisms
- Orbit control electronics
- Active methods for stabilizing satellite attitude
- Moving parts requiring deployment after orbital insertion

Instead, a StarMesh Global satellite consists of a computer motherboard, multiple transmit-receive radio chips, antennas, a battery, and solar panels. With the total component cost for each satellite and current launch costs per pound, a StarMesh Global satellite can be built and launched for under $50,000.

Using patented technology, StarMesh Global can deploy 200 satellites to support worldwide data communication between ground stations without relying on third-party global positioning satellites.

This system would cost approximately $20 million—dramatically less than the billions required for current systems.

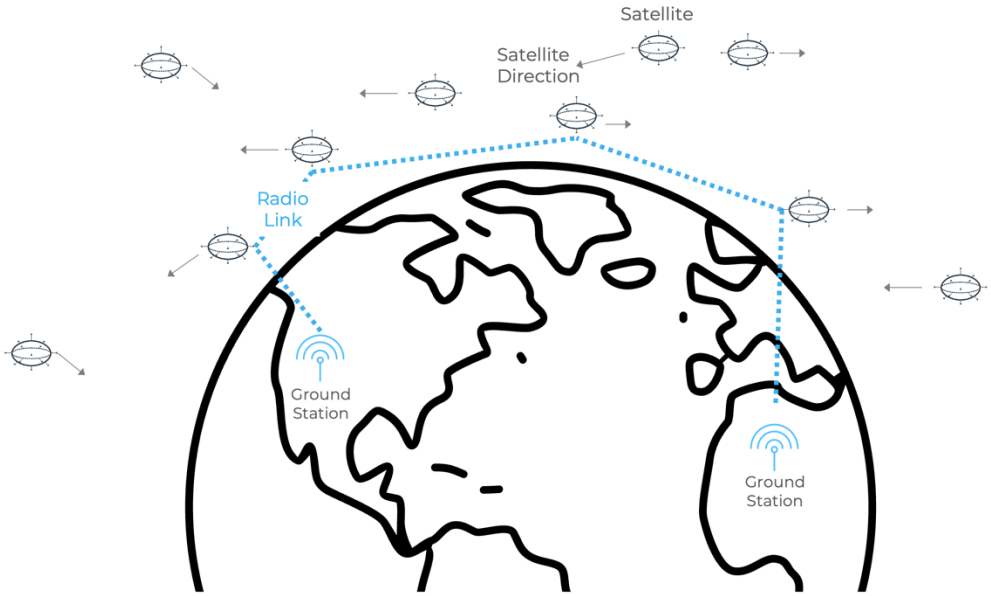

Figure 1

Figure 1 provides a simplified representation of part of the StarMesh Global satellite constellation. These satellites are stochastically distributed, a pattern that becomes more apparent when observed from the Earth's surface. As the system evolves, the orbital paths of individual satellites may drift, with some gradually moving to different altitudes, even though they were initially launched at the same level.

Radio links between satellites and ground stations, and potentially in conjunction with GEO systems, are established based on the statistical likelihood that a large enough constellation will reliably produce radio links of sufficient quality. This enables the creation of robust communication routes between any two ground stations. StarMesh Global's patented routing technology allows satellites to assemble these radio links autonomously into the most efficient route between ground stations—all without needing an external routing computer.

Despite this innovation, numerous technical challenges must be addressed to fully implement a global, space-based communication network. StarMesh Global's patent portfolio outlines advanced routing algorithms and antenna designs that facilitate the pairing of antennas between satellites and ground stations, ensuring the creation of optimal radio routes across the entire network.

III. A StarMesh Global System Supports Communications in Various Environments

This section explains techniques to ensure that a StarMesh Global satellite communication system will support commercially practicable systems.

a. Diversity Scheme

A diversity scheme in telecommunications enhances the reliability of a message signal by using two or more communication channels with varying characteristics. This involves dividing a digital character string into segments, each with a checksum code generated by a specific algorithm. These segments and checksums are transmitted to a receiving node, where a computer uses the checksums to verify the integrity of each segment.

In a system employing diversity, the sending node retransmits the signal, either slightly later, on a different frequency, via an alternate route, or using a spread spectrum with a second set of codes. This results in multiple transmissions of the same content, ensuring that the received data accurately reflects the original message. Different methods of diversifying signal transmissions can be combined to enhance reliability further.

A StarMesh Global system can utilize any of these diversity schemes to ensure data integrity, with an initial expected error rate of less than 1%.

b. Bent Pipe Routes & Routes with Satellite-to-Satellite Links

In the 1950s and 60s, Richard Bellman of the Rand Corporation developed the concept of 'dynamic programming,' which calculates optimal routes from multiple subroutes. However, Bellman's method requires all routing information to be centralized in a single computer, which becomes impractical as the number of nodes increases, leading to excessive radio traffic and computational strain.

StarMesh Global overcomes this limitation by leveraging a new approach that capitalizes on the fact that an optimal multi-node route is identical in both directions. The techniques described in StarMesh Global's patent portfolio use this principle to analyze radio signals between nodes, allowing them to generate optimal routes independently. For instance, a route can be created from one ground node to another, and those nodes can then send data back to the first node using the same route in reverse.

This decentralized method of route creation significantly reduces the computational load on each node, eliminating the need for a central system to manage and calculate routing information.

c. Antenna Design

Phase-delay beam generation allows multi-feed parabolic antennas to create narrow radio beams aimed precisely in the intended direction. However, even with accurate satellite locations and orientations, antenna sidelobes can still interfere with the radio link if the antennas of two satellites are not perfectly aligned. While more advanced designs like phased-array flat panel antennas could enhance inter-satellite connections, these solutions significantly increase the already high cost of satellite systems.

Instead of relying on more expensive antenna designs, StarMesh Global leverages probability and statistics to select antennas on its satellites. For distances under a thousand miles, satellites with relatively low-gain antennas can still establish satisfactory links, even if the likelihood of a direct link between any two satellites is low. For instance,

with each satellite covering about 30% of the space around it, the probability of forming a direct link is around 9%. However, with multiple satellites in the system, StarMesh Global can identify numerous potential routes, ensuring that even low-cost antenna designs can provide the best path. This approach also allows for flexible satellite design, including low-cost CubeSats equipped with planar antennas.

d. Using Signal Quality to Create Routes

Traditional dynamic programming methods focus on minimizing route length, but this approach doesn't work in systems where nodes move relative to each other and antennas can't always pair up. Instead, StarMesh Global creates routes based on parameters that assess the quality of radio signals between nodes, ensuring reliable data transmission. These parameters may include signal-to-noise ratio or filtering out routes with signals below a specified strength.

e. Bandwidth

In a StarMesh Global system, total bandwidth relies less on individual satellites' capacity than in traditional systems. The low cost of StarMesh satellites allows for more satellites to be deployed, which increases the overall bandwidth by providing more available satellites for data transmission. With more satellites in orbit, multiple routes to a given destination become possible, allowing routing algorithms to select alternate paths when many ground stations transmit data dynamically. This effectively reduces the load on any satellite, enhancing overall system performance.

f. Bent Pipe Failures

Due to the probabilistic nature of StarMesh Global's route creation, a single satellite's antennas may not always align with antennas at two ground stations simultaneously. To address this, StarMesh Global patents propose two solutions.

One approach is to spin the satellites, allowing each satellite to present six to eight antenna orientations during route creation. The other approach involves using onboard computers to execute routing algorithms that establish links and routes through multiple satellites when a direct 'bent pipe' route is unavailable.

g. Route Stability

With satellites moving at 18,000 miles per hour (five miles per second), multi-satellite routes can be unstable. However, estimates suggest that a route will remain stable for four seconds. Using StarMesh Global's patented route creation methods, new routes can be established within one second, allowing data transmission to continue seamlessly during the four-second window of route stability.

In summary

StarMesh Global represents a transformative step forward in satellite communication technology. By drastically reducing costs and complexity while maintaining robust, reliable service, StarMesh Global’s innovative approach is set to disrupt traditional

satellite systems and make space-based communication more accessible than ever before.

Leveraging a decentralized network of low-cost satellites, advanced routing algorithms, and a highly flexible design, StarMesh Global offers a powerful solution to meet the growing demands of global connectivity.

As we continue to develop and refine our technology, we remain committed to revolutionizing the satellite communications industry and opening new frontiers for data transmission worldwide.

The future of satellite communication is here, and it is StarMesh Global.

About StarMesh Global

StarMesh Global has evolved from a conceptual think tank into a technology development and engineering leader, pioneering groundbreaking satellite designs and communications systems. Leveraging low-earth orbit satellite networks, StarMesh provides global connectivity at a fraction of the cost of traditional industry solutions.

With its extensive international patent portfolio, StarMesh drives innovation and disruption across the aerospace, defense, and communication sectors while enabling various commercial applications.

To learn more, visit www.starmeshglobal.com.

Please direct questions to:

Charles W. Chamberlain
Chief Operating Officer & Business Development
cchamberlain@starmeshglobal.com