Introducing STARMESH GLOBAL™ Satellite Communications

Many players are pursuing global communications via satellite, but currently proposed low earth orbit (LEO) systems require enormous investments to engineer, build, and launch a hundred or more satellites for serving a given swath of the earth's surface. Both geostationary (Geo) and LEO systems use heavy, mechanically complex satellites that involve extensive engineering, precision construction and high launch costs, as well as requiring complex telemetry and software to deploy and maintain them in particular orbits. These and other costs have limited the number of players in this burgeoning new field to those who already had, or have been able to raise, hundreds of millions of dollars.

STARMESH GLOBAL™ communication systems are based on unique patented technology[1] that will make obsolete the heavy, complex, and costly satellites now being used in satellite communications, both for Internet and cellular telephony. The satellites' orbital paths, altitudes, and orientations are not controlled once the satellites are in orbit. This slashes the cost to design, build, launch, and operate satellite communication systems, potentially to about 1% or less than the cost structure of currently known systems. The cost savings inherent in this technology, when it is fully developed, will revolutionize the industry.

STARMESH GLOBAL™ has developed and owns a large worldwide patent portfolio relating to stochastically distributed satellites that automatically route data transmissions throughout a satellite constellation with no central or controlling intelligence, automatically select optimum routes based on radio parameters such as signal/noise ratio, and automatically pair antennas in the satellites without controlling their attitude (pitch, roll, and yaw). This revolutionary new technology relies on a statistical near-certainty that a sufficient number of its low-cost satellites can be placed in orbit so that there will always be enough of them located relative to each other and within sight of originating and destination ground stations to support data communications. This represents a completely different paradigm from previous approaches that created radio links and routes by knowing the precise positions and attitudes of the satellites and using a central computer to calculate routes through the system.

This paper discusses the technical and commercial background against which STARMESH GLOBAL™ patented its revolutionary new approach to satellite communications and summarizes some of the features that result in its potential to disrupt the satellite communication industry now being built on heavy, complex, and expensive satellites.

I. Satellite Internet Today

By 2015 engineers and scientists around the world had begun to envision a major technological sector using satellites to provide Internet on a worldwide basis. One of the first goals sought to provide Internet access in the vicinity of the Equator, a large portion of the population of which comprises people in remote areas, on islands, and in underdeveloped countries. As noted, these efforts have engendered investments in the hundreds of millions, and even billions, of dollars.

1. The STARMESH GLOBAL™ international patent portfolio is available at www.starmeshglobal.com.

Among the factors driving this new field is the dramatic reduction in cost and weight of electronic components used in communications satellites. Cost is important for obvious reasons, and reduced weight results in lower launch costs. However, an important point to keep in mind is that even larger markets are potentially available to systems that can supply significant, system-wide bandwidth, which would allow direct competition with existing terrestrial Internet networks, telephone systems, and streaming video services.

STARMESH GLOBAL™ has invented low earth orbit (LEO) satellite systems that can satisfy that goal with its low-cost satellites for pennies on the dollar without compromising the quality of service.

II. STARMESH GLOBAL™—A New Approach

STARMESH GLOBAL™ is a think tank headquartered in the Princeton, NJ, area, dedicated to creating the technical foundation for an entirely new way of communicating via satellite, particularly as applied to satellite Internet. STARMESH GLOBAL™ is looking to transition to a development company to launch a proof-of-concept satellite system, and eventually to seeking a way to monetize its breakthrough technology.

Satellite cost is one of the biggest obstacles to the realization of space-based communications systems. Already in 2020 the worldwide total revenue from satellite companies is estimated to be about 20 billion dollars. As noted, creating that revenue takes an investment of the same or similar order of magnitude. While generally this expense can be amortized over the life of the system, say 10–15 years, potentially making the system profitable over its useful life, the necessary upfront outlay is still required to design, build, and launch the system, not to mention the cost of maintaining it by replacing the costly satellites when they malfunction and controlling the satellites' orbits and orientations.

The STARMESH GLOBAL™ approach slashes the cost by paring down the satellites in a way that eliminates major sources of weight, component cost, and design complexity. The result is satellites without any of the following conventional features:

- Rocket thrusters
- Rocket fuel
- Solar sailing (using solar panels to provide thrust)
- Orbit control electronics
- Active methods for stabilizing satellite attitude
- Moving parts requiring deployment after orbital insertion
- Components (such a solar panels) extending outside the main satellite housing

As presently contemplated, a STARMESH GLOBAL™ satellite will consist essentially of a computer mother board, multiple transmit-receive radio chips, antennas, a battery, and solar panels. A high end mother board, including a computer chip is available today at less than one thousand dollars. Batteries and solar panels are relatively inexpensive. Thus, the component cost could be less than two or three thousand dollars. Manufacturing should be straight forward, and launch costs are now about two thousand dollars per pound. The upshot is that a STARMESH GLOBAL™ satellite can probably be built and inserted into orbit for less than $10,000.

Operationally, the STARMESH GLOBAL™ patented technology enables a constellation of 200 or so of these satellites to support worldwide data communications between specified ground stations, and in many implementations does not rely on third-party global positioning satellites. A system of 200 satellites would cost only $2,000,000, as compared to current systems being actively pursued that have costs potentially reaching multiple billions of dollars.

Figure 1 is a simplified depiction of a portion of a STARMESH GLOBAL™ satellite constellation. The satellites are stochastically distributed (which would be more apparent looking up from the surface of the earth). Their orbital paths are free to vary as the system ages, and the satellites might migrate to different altitudes even if they were all originally inserted into orbit at the same altitude.

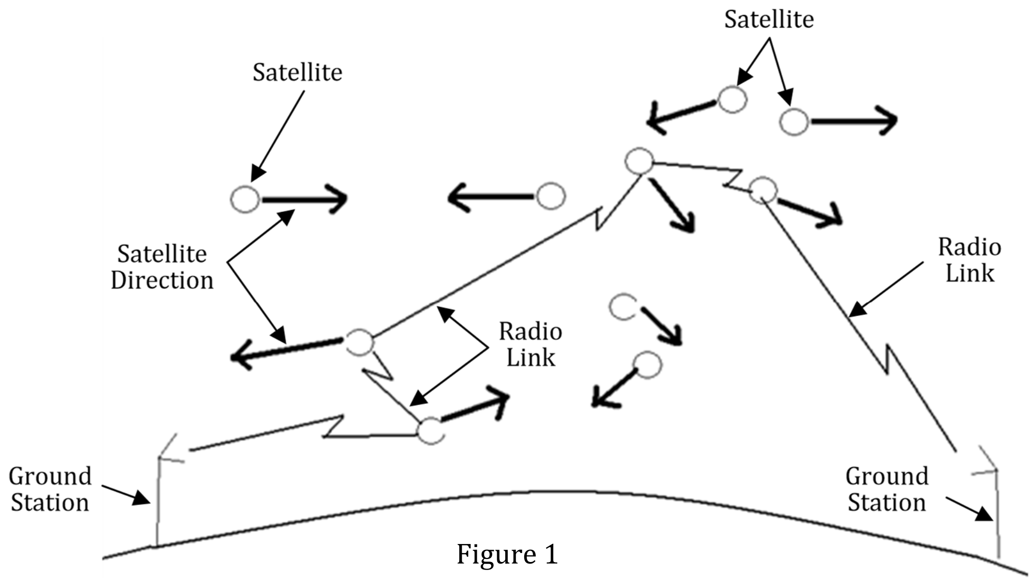

Figure 1

The creation of radio links between satellites and between satellites and ground stations, and potentially in conjunction with Geo systems, relies on the statistical likelihood that with a large enough constellation of satellites, radio links with sufficient quality can be assembled to create radio routes between any two ground stations. Even though the satellite distribution seems hopelessly chaotic, the routing technology patented by STARMESH GLOBAL™ enables the satellites themselves to assemble radio links into a preferred route between ground stations—all without a separate, central routing computer.

Nevertheless, those familiar with satellite communications will immediately realize that there are numerous technical issues that have to be addressed to implement a worldwide space-based communication system. The STARMESH GLOBAL™ patents describe routing algorithms and antenna constructions that enable pairing of antennas between satellites and satellites and ground stations, and creation of optimum radio routes between ground stations.

III. A STARMESH GLOBAL™ System Supports Communications in Various Environments

Even though the patented STARMESH GLOBAL™ route creation approach is ground breaking, there is more to satellite communications than creating a route that can deliver data from one ground location to another. This section explains techniques that will ensure that a STARMESH GLOBAL™ satellite communication system will support commercially practicable systems.

a. Diversity Scheme

A diversity scheme in telecommunications refers to a method for improving the reliability of a message signal by using two or more communication channels with different characteristics.[2] The concept involves sending a digital character string divided into separate segments each with a check-sum code generated by a particular algorithm. The segments and their associated check-sums are transmitted over the data channel to a receiving node. The check-sum characters are used by a computer in the receiving node to verify the integrity of the respective segments.

In a system employing diversity, the sending node sends the signal again. This can be done at slightly later time and in the same fashion as the original transmission, on a second frequency, over an alternate route, or in spread spectrum with a second set of codes. This results in transmissions of the same content in diverse ways, with the goal of ensuring that the content of the received transmission reflects the original content sent by the sending node. And different ways of diversifying the signal transmissions can also be combined to create even greater diversity.

A STARMESH GLOBAL™ system can employ any of these diversity schemes to ensure the integrity of the data even though the system may in practice have an initial error rate of 1% or so.

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

In the 1950s and 60s Richard Bellman of the Rand Corporation wrote extensively on the subject of creating optimum routes from multiple subroutes, including pioneering a concept known as “dynamic programming.” However, Bellman’s dynamic programming requires all relevant routing information to be sent to a single computer for optimum route calculation. When the number of nodes in a system becomes too large, the amount of radio traffic absorbs all of the radio spectrum and computer time.

The STARMESH GLOBAL™ approach uses a new method that takes advantage of the fact that an optimum route in a multi-node route is the same in both directions. Techniques described in the STARMESH GLOBAL™ patent portfolio uses this law of radio transmissions to create sophisticated algorithms that can employ artificial intelligence to analyze attributes of radio signals exchanged by the nodes whereby the nodes themselves create optimum routes. For example, in one application a route is created in one direction, from a particular ground node to other ground nodes, and the other ground nodes can then send data content addressed to the first ground node in the other direction on that route.

The result is totally decentralized route creation, with each node having a limited computational load. The need to collect routing information in a central location for optimum route calculation is eliminated.

2. *See* “Diversity Scheme,” wikipedia.org/wiki/Diversity_scheme.

c. Antenna Design

The physics of radio antennas is dauntingly complex. Multi-feed parabolic antennas are common, and phase delay can be used to create radio beams. In typical satellite systems the location of the nodes is controlled or known, and the antennas can create narrow beams pointing in very precise directions. However, that requires accurate knowledge of node location and attitude. But even if precise satellite locations and orientations are known, there may still be antenna foot prints with side lobes. If the antennas do not line up exactly with an antenna of a potential connecting satellite, the resulting radio link may be weakened and the side lobes can create unintended radio interference.

To avoid many of the antenna design issues facing conventional communication satellite designers, a STARMESH GLOBAL™ system lets probability and statistics select antennas on the satellites. For distances of less than about a thousand miles, relatively low gain antennas can create satisfactory links. However, the probability of a link between two satellites can be low. For example, if each satellite has antenna coverage of only about 30% of the spherical space around itself, then the chances of establishing a useful inter-satellite link can be estimated at 9%. If multiple potential routes (bent pipe or multi-satellite) are available, letting the system select its own route as in the STARMESH GLOBAL™ approach avoids this problem.

d. Using Signal Quality to Create Routes

Most applications of dynamic programming rely on minimizing route length. Obviously that won't work in a system where the nodes are moving relative to each other and may not support a route because the antennas on different nodes can't be paired. Instead, route creation in a STARMESH GLOBAL™ system is based on one or more parameters that reflect the quality of radio signals received by the nodes as it relates to their suitability for supporting data transmissions. This quality can be one or more of a variety of parameters, such as maximum signal to noise ratio, or elimination of routes with links below a given signal strength.

e. Bandwidth

In a STARMESH GLOBAL™ system the amount of system bandwidth is less dependent on individual satellite bandwidth than in a conventional system. This is because the low cost of the satellites allows bandwidth to be increased by placing more satellites in orbit so that on a statistical basis more satellites are available for data transmissions and multiple routes exist to a given destination. That is, increasing the number of satellites in the constellation increases the number of potential routes from one ground station to another. Routing algorithms can be used to create another route to a particular destination if a large number of other ground stations are seeking to transmit data to that destination. And with more satellites available the potential load on any particular satellite will be reduced,

f. Bent Pipe Failures

Given the probabilistic nature of the STARMESH GLOBAL™ route creation process, it is possible that the antennas of a single satellite might not line up with the antennas at two ground stations at any given time. The STARMESH GLOBAL™ patents describe two ways that overcome this type of failure to create a bent pipe route.

One is to spin the satellites such that an individual satellite can present from six to eight different antenna choices during a route creation interval. The other involves using computers in the satellites to execute routing algorithms that create links and routes between multiple satellites when a bent pipe route is not available.

g. Route Stability

With the satellites moving at 18,000 miles an hour (five miles per second), multi-satellite routes can be fragile. It is estimated that a route should be stable for at least four seconds. With the patented methods of route creation, new routes can be created within one second, and thus be available for data transmission during the four seconds that the route exists.

IV. Summary—Putting It All Together Using an Example

As an example, take a system with a single origin of desired communication, say a ground station in Cairo, Egypt, that has cable Internet access. Assume further that the destination is a truck driver in Cape Town, South Africa, who has Internet access via a hot spot or personal device, and wants information on oil prices.

Assume that a first satellite is over Namibia (SW Africa) and a second satellite is over central Mozambique (SE Africa). Although there might be 10–18 satellites over the approximate region of Zaire (Democratic Republic of the Congo) close to Namibia and Mozambique, this example assumes that at least some of them will be able both to connect to a Cairo route and also match antennas with either the Namibia or Mozambique satellite.

The Namibia satellite has just received several messages noting that those satellites can reach Cairo from satellites over DRC. The Namibia satellite remembers which incoming antenna provided which message. The Namibia satellite compares messages, and calculates a figure of merit for each one that includes the figure of merit (such as signal strength) sent by the satellites over the DRC and adds information about the new receiving link and creates a new figure of merit. The Namibia satellite now chooses the incoming link with the best figure of merit.

At this point, the Namibia satellite transmits on multiple antennas a new message containing only two pieces of information: that this satellite can reach Cairo, and that the route would have a specific figure of merit indicative of its suitability as a link in a radio route to Cape Town. The satellite does not need to know and does not transmit the entire route.

The Mozambique satellite also sends a message using a procedure similar to that employed by the Namibia satellite.

A potential user, such as the truck driver in Cape Town, receives these two messages, which have arrived at the hot spot or personal device on different antennas. The user software calculates a figure of merit for each message (i.e., antenna) and transmits a message toward Cairo on the preferred antenna with the oil-price question and the user's identity. This message is forwarded to

Cairo, which accesses the answer from the Internet and transmits it to Cape Town over the same route that carried the message.

Thus, the entire route does not reside in any memory at any ground station or in any satellite or at any central controlling computer, but optimum routes between ground stations are nevertheless created automatically and nearly instantaneously. This highly efficient, decentralized route creation technique virtually eliminates system overhead.