THE DEVELOPMENT OF STARMESH GLOBAL™ Satellite Technologies

This paper presents various aspects of the stochastic/random orbit satellite concept underlying pioneering STARMESH GLOBAL™ LEO ("Low Earth Orbit") technology, with reference to the nine patent families (below), which can be accessed from our website at www.STARMESHGLOBAL.com. Many of the same topics and concepts are discussed in our White Papers No. 1 and No. 3 (also available on our website), but this paper covers them in greater detail and with specific references to salient features disclosed in Star Mesh's extensive international patent portfolio.

Star Mesh has nine standalone patent families (Families A through I) that reflect the evolution of its pioneering satellite communication technology from its beginning in 2016 when we filed our first patent applications. We started by patenting a unique system for providing service between two ground stations via a single new type of satellite (a so-called "bent pipe"). We obtained—and continue to pursue—patents around the world on increasingly complex technology for routing communications using satellites and drones. Our patent portfolio covers numerous systems with novel LEO satellites (and drones in some cases) that use sophisticated ground-to-air and multi-satellite (and multi-drone) routing algorithms capable of exploiting artificial intelligence to provide space-based internet to users around the world. The summaries here of our current Patent Families illustrate the progression and refinement of STARMESH GLOBAL™ LEO satellite systems from their inception to the present.

<u>FAMILY A:</u> U.S. Patents No. 10,084,536 and No. 10,998,962: "Bent Pipe"

The '536 patent introduced the groundbreaking STARMESH GLOBAL™ reverse-routing technique in which computers in satellites create routes in one direction, from a sending ground station to a receiving ground station, and then transmit data in the opposite direction from the receiving ground station back to the sending ground station. (Our White Paper No. 3 also summarizes how this works.) Strictly using onboard computers, the STARMESH GLOBAL™ satellites by themselves, along with computers at the ground stations, create high quality, single-satellite radio routes between two ground locations, without the need for separate system-wide computers to make routing decisions. Subsequent families build on basic concepts disclosed in these patents.

The following lists some foundational features of the prototypical reverse-routing STARMESH GLOBAL™ satellite communications systems introduced in this family:

- Stochastically distributed satellites with no control over their geolocation or attitude, thus allowing them to "tumble" as they orbit without the ground stations knowing where they are.

- Low-cost, lightweight satellites as small as 8–16 inches in diameter using directional parabolic antennas about 4–6 inches in diameter operating at typical satellite frequencies.

- High-gain directional parabolic antennas on the small STARMESH GLOBAL™ satellites that support bent pipe communications.

- Satellite directional antennas arranged to transmit and receive over as much as possible of the spherical space surrounding them and ground stations with directional antennas that transmit and receive over as much as possible of the spherical space above them.

Route creation is possible—in spite of the fact that the ground stations don't know where the satellites are—because there are enough stochastically distributed satellites in orbit that the probability at least one satellite will <u>not</u> be visible from every ground station at any given time is only 1 in 4,000,000. See the '536 patent at column 8, lines 16–34. Radio links are created when a directional antenna at a ground station dynamically aligns with a directional antenna on a visible tumbling satellite, even though the ground stations can't create links with pre-chosen satellites as in existing systems. This "real-time dynamic antenna pairing" makes STARMESH GLOBAL™ satellites lighter and less expensive to build and launch, both made possible by eliminating heavy propulsion systems and their fuel.

This family recognizes the particular importance to the performance of a system of stochastically distributed satellites of design variables such as satellite altitude, antenna gain, and percentage of the satellite surface available for the antennas. Judicious engineering should be able to increase the portion of the satellite surface comprising antennas and substantially improve bent pipe performance.

This Patent Family A further includes a pending application (Pub. No. US 2021/0344412) which will extend existing coverage of these foundational aspects of STARMESH GLOBAL™ technology.

<u>FAMILY B:</u> U.S. Patents No. 10,447,381 and No. 11,038,586: "Rotating Satellites"

An improvement added by these patents to Bent Pipe Family A is spinning the satellites to improve the statistical opportunities for route creation. For example, one revolution per second will increase the chances of creating a radio link with a satellite, including links between satellites. In one of many possible variations on this basic idea the satellites would spin about different, randomly oriented axes. Depending on the number of antennas, this will present six to eight more chances of having antennas on the satellites align with antennas at the ground stations in a given period of time. In another adaptation slightly variable spin rates could further enhance the probability of making radio links.

Rotating the satellites raises issues of signal strength and signal-to-noise because rotating satellites have less time during which their antennas are linked. However, the antenna design described below in Patent Family C addresses these issues and will improve signal strength, while Patent Family E below further describes a method for controlling satellite spin rate.

This Patent Family B also includes a pending U.S. application (Pub. No. US 2021/0399793) that will enable Star Mesh to continue to tailor and expand the scope of STARMESH GLOBAL™ intellectual property as we and the satellite-based communications industry continue to evolve. This family includes 12 foreign patents, with pending applications in four more countries.

<u>FAMILY C:</u> U.S. Patents No. 10,085,200, No. 10,791,493 and No. 11,356,921: "Star Antenna"

When increasing the amount of data over a radio channel, the radio bandwidth increases proportionally and the receiver (whether an amplifier, correlation device, or other type) receives an increased proportional amount of background noise. One solution would be to increase transmitter power, but decreasing the antenna beam width instead can provide a compensating result for a greater data rate. As a step in that direction, this family suggests several solutions:

- Use larger antennas to reduce beam width.

- Use antennas with multiple feeds to direct narrow antenna beams more accurately. Antennas used in many existing systems that rely on knowing satellites' locations and orientations create beams with side lobes and gaps in coverage. The narrow beams of STARMESH GLOBAL™ multi-feed directional antennas enhance the probability of creating high quality radio links to support real-time dynamic antenna pairing by producing better reception and requiring less transmitted power (and thus fewer solar panels).

- Use narrow light beams rather than radio signals to increase bandwidth.

This family of StarMesh™ patents includes pending U.S. application no. 17/752,912 that will enable us to enhance protection of our pioneering technology. It also includes a Chinese patent and pending applications in 12 countries, including the European Patent Office.

FAMILY D: U.S. Patents No. 10,291,316, No. 10,784,953 and 11,206,079: "Routes by Orbital Knowledge"

Some conversations in the traditional satellite communications industry were tending toward development of systems in which all satellites know their own orbits. The patents in this family extend that concept to the proprietary STARMESH GLOBAL™ approach, which uses satellites in unconstrained orbits, to the special case wherein the satellites know their own orbits and the orbits of all the other satellites. The routing algorithms disclosed in these patents use the orbital information of all the satellites to create single- and multiple-satellite radio routes.

These STARMESH GLOBAL™ routing methods can disseminate information virtually simultaneously throughout a constellation of satellites distributed worldwide, which enables the creation of a secure distributed ledger physically located 100% in space. This property of the STARMESH GLOBAL™ system will be useful in various blockchain applications and the implementation of digital currencies.

This Family D also includes a pending U.S. application (Pub. No. US 2021/0231758) that will enable STARMESH GLOBAL™ patent coverage to continue to account for future developments in this type of satellite-based communication. It also includes pending applications in 12 foreign countries, including the European Patent Office.

FAMILY E: U.S. Patent No. 10,979,136: "Routing Algorithms for Stochastic-Orbit Satellites"

There are a dozen or more inventions disclosed in this patent. Another U.S. application (Pub. No. US 2021/0344409) and 15 foreign counterparts based on this comprehensive disclosure have been filed as part of our intellectual property strategy. In some ways this application represents a culmination as of its filing date of work done to extend the reach of the STARMESH GLOBAL™ technology disclosed in the earlier patent families discussed above.

A major emphasis in this family is the creation of links and routes with satisfactory signal strength to enable new types of satellite-based systems, methods and algorithms. The disclosed proprietary routing algorithms are adaptable to implementation by artificial intelligence to enhance a satellite's ability to analyze attributes of radio signals exchanged by system nodes as the satellite's time in service increases. Together with the technological concepts in the earlier patent families (above), the disclosure in the '136 patent provides a multi-faceted toolbox for designers of satellite communications systems.

The following outlines some of the salient aspects of these systems and methods with reference to figures in the patent. The discussion that follows here provides a closer look at some of the pioneering characteristics of the StarMesh™ proprietary routing solutions described in this patent.

Part I. The STARMESH GLOBAL™ route creation system in the '136 patent selects from millions of potential routes, with the optimum route being based on maximizing signal quality over the entire route and not using links with poor signal quality. It required many new and unique steps and measurements to conceive decentralized systems, methods and algorithms that spread the route creation computational load across multiple nodes.

Preliminary communication between nodes for route creation is almost eliminated since each node makes its own routing decisions. The amount of computation required by each node in a multi-stage decision process is greatly reduced. Route creation is totally decentralized as no controlling or central computer is needed. Even though the stochastic distribution of the satellites, and a typical orbital velocity of 18,000 mph, limit the time any particular node-to-node link in a route remains stable, the StarMesh™ algorithms are powerful enough to refresh existing routes or create new routes at suitable intervals (say every three or four seconds). This is sufficient to support multiple data transmissions, which take only a fraction of the time that a route between particular ground locations is stable. Further transmissions are seamlessly conveyed by the refreshed or newly assembled route. Figure 6 of the '136 patent and the accompanying text present a route "spanning tree" example that embodies this concept.

A criteria (or "figure of merit") indicating the quality of a potential link in a route is determined by each satellite and used by the satellite's onboard computer to execute its part of the routing algorithm. Potential examples are: elimination of sub-routes with the weakest signal strength or exclusion of sub-routes with a figure of merit below a certain threshold. Any list of variables including remaining battery life, length of queues of unsent messages, signal-to-noise ratio and other parameters, thresholds, or rules can be used in calculating an appropriate figure of merit. Many of the exemplary criteria embodying the figure of merit can be expressed as a single digit, which reduces the processing time required in the satellites.

Part II. An important consequence of the new routing techniques in the '136 patent is its utility in the Bent Pipe system. See Family A. STARMESH GLOBAL™ Bent Pipe systems in their first attempt might obtain only about 70% of the required connections. When given a case of no-route, the more robust routing technology in present Family E will automatically create a multi-link route to send the data. Figure 10 of the '136 patent illustrates an example whereby GN1 ("ground node") wants to send data to GN2. However, L89 ("linking satellite") and L162 and others do not have antennas that line up. Therefore, a route (four links) is automatically created for data transfer. In other words, a STARMESH GLOBAL™ system will almost always have a route from a particular originating ground location to a desired destination, even if it requires satellite-to-satellite links.

For example, assume that Cairo has a good cable connection. Cairo desires to send a packet to southern Egypt near Sudan, but no single-satellite connection is available to create a Bent Pipe route. The routing protocols in the '136 patent permit the packet instead to be instantly sent to a satellite over Saudi Arabia, say, then perhaps to one near Greece, then possibly to one over England, then one to over Libya, and finally to the destination in southern Egypt.

Part III. One embodiment in the '136 patent discloses a non-spherical satellite with solar panels on top and antennas pointing to the side and bottom. This should permit a slight decrease in the number of transceivers required. This will also increase the horizontal coverage of the antennas and provide better statistical results. See Figures 12 and 14 of the '136 patent.

This satellite design requires addressing the problem of satellite orientation, which can be achieved using electromagnetic rods (Figure 16 of the '136 patent) actuated in a predetermined fashion to interact with the earth's magnetic field. This same construction can control the satellite's spinning rate. In this system, the spin rate of satellites in a multi-link satellite route will spin more slowly than discussed in other patent families, perhaps at rates of one or two revolutions per minute.

The '136 patent also discloses a way of maintaining a satellite oriented to within ±10° of horizontal. This will enhance the stability of a given route by maintaining internodal antenna pairing for longer periods. In other words, the precision control of satellite orientation employed by other satellite communication systems is not required to support the innovative routing algorithms disclosed in the '136 patent.

Part IV. STARMESH GLOBAL™ routing technology supports satellites orbiting at different altitudes. Routes can be selected that use higher altitude GEO ("Geosynchronous") or MEO ("Medium Earth Orbit") satellites for long routes that can minimize the number of links. Although the '136 patent satellite environment appears to be chaotic, route creation based on route quality will be very effective in creating multi-satellite routes. Some idea of how this works can be seen by considering Figures 9 and 22 of the '136 patent and the description of the route creation process in the text associated with those figures. Figure 22 also illustrates how STARMESH GLOBAL™ systems can incorporate drones and balloons as nodes that connect directly with vehicles and personal communication devices.

FAMILY F: Pub. No. US 2021/0359751: "Data Transmission Diversity"

This family uses known "diversity" techniques to minimize errors in data transmitted via the unique STARMESH GLOBAL™ satellite communication systems. While our systems in all of their forms represent a leap in satellite communication technology, they still require data transmissions by and between satellites that may be thousands of miles apart and moving at 18,000 mph. See Family E, Part I. This Family F applies a technique for preserving the integrity of data transmitted over radio links whose quality may change as satellites in a given route move relative to each other.

In one embodiment particularly applicable to multi-satellite routes, a satellite with data onboard will transmit it to the next satellite using at least two different technologies ("format diversity"). The '751 publication gives examples of four conventional technologies that might be used in various combinations to provide format diversity:

(1) frequency modulation used in cellular telephony,

(2) code division using Qualcomm Inc.'s code division multiple access technology ("CDMA") to send multiple signals simultaneously in the same frequency band,

(3) frequency division using frequency division multiple access technology ("FDMA") to send a given signal simultaneously on two different frequencies, and

(4) time division using time division multiple access technology("TDMA") to send a given signal twice but at different times.

Data signals are assembled into packets with conventional error-coding information to which each receiving satellite applies the appropriate error-correction algorithm. It transmits the corrected data to the next satellite in the route in at least two of the available formats. See Figure 4 of the '751 publication. Each satellite in the system has a look-up table populated during route creation that determines the format in which to send a corrected data packet depending on the format in which it was received. In this fashion, the data is corrected by each satellite at every step.

Another embodiment sends data packets via two different routes ("space diversity"). A STARMESH GLOBAL™ routing protocol can identify more than one potential route back to a sending ground station. (This feature is also summarized in our White Paper No. 3.) In a basic application a ground station that receives routing signals from different satellites on different antennas chooses one of the antennas for data transmission according to the algorithm being applied in that particular system. With space diversity the data is transmitted back to the sending (destination) ground station using at least two antennas, each of which is associated with a different route. See Figure 5 of the '751 publication. The destination ground station then applies the appropriate error-correction algorithm to reassemble the original data packet. In a further variation both signal diversity and format diversity are applied to the data transmissions, also illustrated in Figure 5.

FAMILY G: Pub. No. US 2022/0029699: "Aerodynamic LEO and VLEO Satellites"

Using low altitude satellites as nodes in satellite communications systems has several advantages. Signal strength increases as the distance between antennas decreases, so that low-flying satellites will more readily connect directly with personal devices on the ground such as smartphones, tablet computers, etc. This will give users more opportunities to access the internet without connecting to a separate system ground station. Lower orbits also reduce the amount of power required to link the satellites with the ground, which in turn reduces the number of batteries and solar panels the satellites have to carry, making them even lighter and less expensive.

In addition, keeping the satellites in lower orbits will ensure against collisions with satellites already in service orbiting above them. The most critical requirement is ensuring the safety of the 250-mile high International Space Station. Satellites in higher orbits will require onboard propulsion to maintain them above the ISS, as well kill systems to destroy them if they lose power (which itself will create hazardous space junk). Any satellite orbiting at a lower altitude will be subject to more severe orbital decay from increased atmospheric drag, but the large size and protruding solar panels on existing communication satellites make the problem worse. If one fails, it will require an expensive replacement, and its sheer size and complexity can result in large pieces surviving reentry and reaching the ground.

The '699 publication discloses a STARMESH GLOBAL™ satellite with a streamlined casing that will reduce atmospheric drag at any altitude, but is especially useful at low altitudes that don't endanger the International Space Station. A regular ellipsoid shape is used as an example, but other streamlined casing shapes are possible. The casing contains the reduced number of internal components characteristic of a STARMESH GLOBAL™ satellite, so the solar panels and antenna mouths can be made flush with the casing surface while minimizing the satellite's effective area in the direction of flight.

The satellites are maintained with the ellipsoid major axis facing in the direction of travel by selective actuation of electromagnetic rods that interact with the earth's magnetic field. See Family E, Part III. In a preferred application electromagnetic rods are also used to maintain the satellite in an orientation that defines a top surface for the solar panels, with antennas on the bottom and sides. However, as with a typical STARMESH GLOBAL™ satellite, this streamlined version has no location or altitude control, and will still cost very little to build and deploy.

This construction permits adoption of several important features, among them being:

- The improved signal strength will permit IoT applications to work through roofs and automobile tops; signal strength can be increased as needed via closed loop power control based on weaker signals received from those types of ground stations.
- A constellation of low-orbit streamlined satellites can be integrated by StarMesh™ routing logic into a system including a higher-orbit backbone of GEO and/or MEO satellites.
- Like all StarMesh™ satellites, this streamlined version can be built and launched at a fraction of the cost of existing communications satellites, so that their inevitable loss due to atmospheric drag at lower altitudes can still be accommodated by building and launching replacements at an expected cost of less than $10K per satellite.
- Being small and light with comparatively few components, the satellites will burn up completely on reentry so dangerous debris doesn't reach the ground.

This family includes a PCT application (Intl. Pub. No. WO 2022/010819).

<u>FAMILY H:</u> Pub. No. US 2022/00173795: "Connecting Moving Users Via Satellites"

This publication describes how STARMESH GLOBAL™ space-based communication technology can serve users moving from place to place on automobiles and airplanes and other conveyances. Many systems described so far assume that the ground stations are fixed and have virtually unlimited power and sufficient room for enough antennas to project narrow, high-power radio beams covering the surrounding semi-spherical space. However, most passenger conveyances have neither the power resources nor the antenna space available in a fixed ground station.

Nevertheless, communications with moving users are made possible by judicious antenna design and placement, combined with the powerful STARMESH GLOBAL™ routing protocols that automatically assemble optimum routes between ground stations. The first step mounts a limited number of wide-beam antennas at available locations on the conveyance that will provide maximum radio coverage in the space around and above the vehicle, airplane, ship, etc. With this arrangement there could be fewer routes (antennas) the moving vehicle will have to choose from for data transmission, but the unique probabilistic nature of the STARMESH GLOBAL™ routing process makes it sufficiently likely that at least one, and possibly more, routes will always be available. And as in systems already described, if a route is not immediately available, it is likely that one or more will become available seconds later in a subsequent route creation phase.

It is also possible that the quality of links established during route creation may be more affected when users as well as the satellites are moving. However, applying the diversity techniques described in Family F will assist in ensuring the integrity of the data content when moving users are on the system.

<u>FAMILY I:</u> Pub. No. US 2022/00173796: "Worldwide Communications Using Drones and Satellites"

This publication describes additional applications of STARMESH GLOBAL™ technology, but it begins with a review of selected important features of the technology and their advantages and applications, many of which are described in the above patent families. This summary will be useful as a "one-stop shop" for anyone seeking a brief overview of some of our technology's capabilities.

Part I. Support for duplex operation, whereby terminal locations (terrestrial ground stations, smartphones, etc.) can transmit and receive content at the same time, is an important aspect of many applications, particularly cellular telephony. The Family B patents describe how to create a duplex bent pipe route. The basic idea designates the satellites as a first type that only transmit in a first frequency band and can only receive in a second frequency band, while the ground nodes are a second type that can only receive in the first frequency band and only transmit in the second frequency band. In this way, the satellite nodes and ground nodes can transmit and receive simultaneously.

However, this makes a multi-satellite route impossible because the satellites can't simultaneously communicate with other. One solution proposed in the Family B patents is a constellation with a certain number of satellites of the same type as the ground stations, but that's only a partial answer since, as illustrated by the following list based on Figure 6 of the '796 publication, only routes with an even number of links are possible:

Link 1: San Francisco Ground Station SF (Type TR) ↔ Satellite S198 (Type RT)*

Link 2: Satellite S198 (Type RT) ↔ Satellite S122 (Type TR)**

Link 3: Satellite S122 (Type TR) ↔ Satellite S86 (Type RT)

Link 4: Satellite S86 (Type RT) ↔ New York City Ground Station NYC (Type TR)

* A two-link route would also be available via a link between satellite S198 and the Denver ground station.

** A three-link route is not available because the Type TR satellite S122 can't communicate with a Type TR ground station.

The '796 publication describes two ways a STARMESH GLOBAL™ system will support a three-link route in this example; from a purely statistical point of view, a route with fewer links (hops) will likely be more stable and have a higher overall quality. One way places antenna sets of both types (TR and RT) at selected ground stations, typically at locations with high population density such as large urban areas. Figure 7 of the '796 publication shows this type of dual-node ground station at Chicago, and illustrates how it identifies more potential routes connected to San Francisco.

Figure 8 illustrates a second approach using ground stations of both types, distributed more or less randomly at cities and regions throughout the system. In addition, the satellite constellation comprises both types, preferably in equal numbers. To preserve the route creation probabilities between any two ground stations the number of satellites is increased.

Part II. The ‘796 publication discloses systems for two specific applications, one capable of serving 100 users and another capable of serving 300 users. Bandwidth availability will be a large factor in determining how many users can be on a system at the same time. The exemplary systems described here permit these large numbers of ground stations to simultaneously access the system by judicious use of a first interval for route creation followed by a second interval for data transmission.

The 100-user system is based on a cyclical, two-phase approach to route creation and data transmission. Routes are refreshed every four seconds, based on an assumption that a route, once created, will maintain its original integrity for four seconds before the satellites have moved far enough to disrupt the route. Timing is provided by satellite and the ground station clocks synchronized to a GPS system. The one-second route creation phase is separated into a number of steps, shown in Figure 9, carried out solely by circuitry in the satellites. At time t = 0 all of the ground stations transmit initial information signals on all of their antennas, as explained in our White Paper No. 3, for 50 msec. The satellites process the initial information signals and send first routing messages in the next 50 msec. Following that initial 100 msec time slot, the satellites send and process successive routing signals (also described in White Paper No. 3) in multiple rounds of successive 100 msec time slots. In a final 100 msec time slot the ground stations process of the routing signals they have received to choose the antenna to use for transmissions to each other ground station.

Creating 10,000 routes interconnecting all 100 ground stations in one second is possible because, among other things, the routing messages sent by the satellites during each 100 msec time slot contain only the information the next node (satellite or ground station) needs to determine if it should link to the sending satellite. This reduces the time and bandwidth required for processing the routing messages received by each satellite and the time required to transmit the next routing messages. Further details on the route creation protocol can be found in the ‘796 publication in the description accompanying Figure 9.

Data is transmitted between ground stations for the three seconds following route creation, after which the routes are refreshed by repeating the four-second cycle. The system can transmit the data in any of the manners already discussed, such as using the diversity techniques described in Family F.

The 300-user system is a variation of the time-slot protocol used to connect 100 users. The 300-user system described in the ‘796 publication uses a system of RT/TR ground stations and satellites as shown in Figure 8 and described above in Part I. It uses the same four-second route creation/data transmission cycle, but with a modified time slot method whereby plural 100 msec time slots are divided into 25 msec subsegments. In the disclosed embodiment the system comprises 300 satellites, and the 300 ground stations send initial information signals in groups of 100 each in successive 25 msec. In the last 25 msec segment of this initial time slot the satellites receiving initial information signals process them in accordance with the basic STARMESH GLOBAL™ route creation protocol. Then, each satellite transmits routing messages in each of three 25 msec segments in succeeding 100 msec. time slots. In the last 25 msec segment of each 100 msec time slot, all of the satellites process the routing messages they received in the previous 75 msec to create links among the satellites. A fuller explanation is not possible in the space available here, but the ‘796 publication contains a complete description at paragraphs 0133–0143.

In this fashion, optimal links are created in each 100 msec time slot rather than in a final 100 msec time slot after all of the rounds of routing messages have been sent. This more efficient manner of creating inter-satellite links permits 300 ground stations to be interconnected in the same one second period as the 100 ground station time slot method. While a complete explanation of this route creation method is beyond the scope of this White Paper, full technical details are described in the '796 publication at paragraphs 0129–0143 in connection with Figure 11.

As in the 100-user system, data is transmitted in the last three seconds of the cycle in accordance with any of the techniques already described. The routes are refreshed in subsequent four-second cycles.

Part III. Star Mesh believes that the future of space-based communications will use low-flying, non-orbiting aerial nodes such as heavier-than-air or lighter-than-air balloons. This part of the '796 publication describes a hybrid system combined with a unique adaption of STARMESH GLOBAL™ routing protocols that can support local area and global communications for large numbers of users.

Figure 12 of the '796 publication, reproduced here, depicts the system used as an example to illustrate the principles underlying this application.

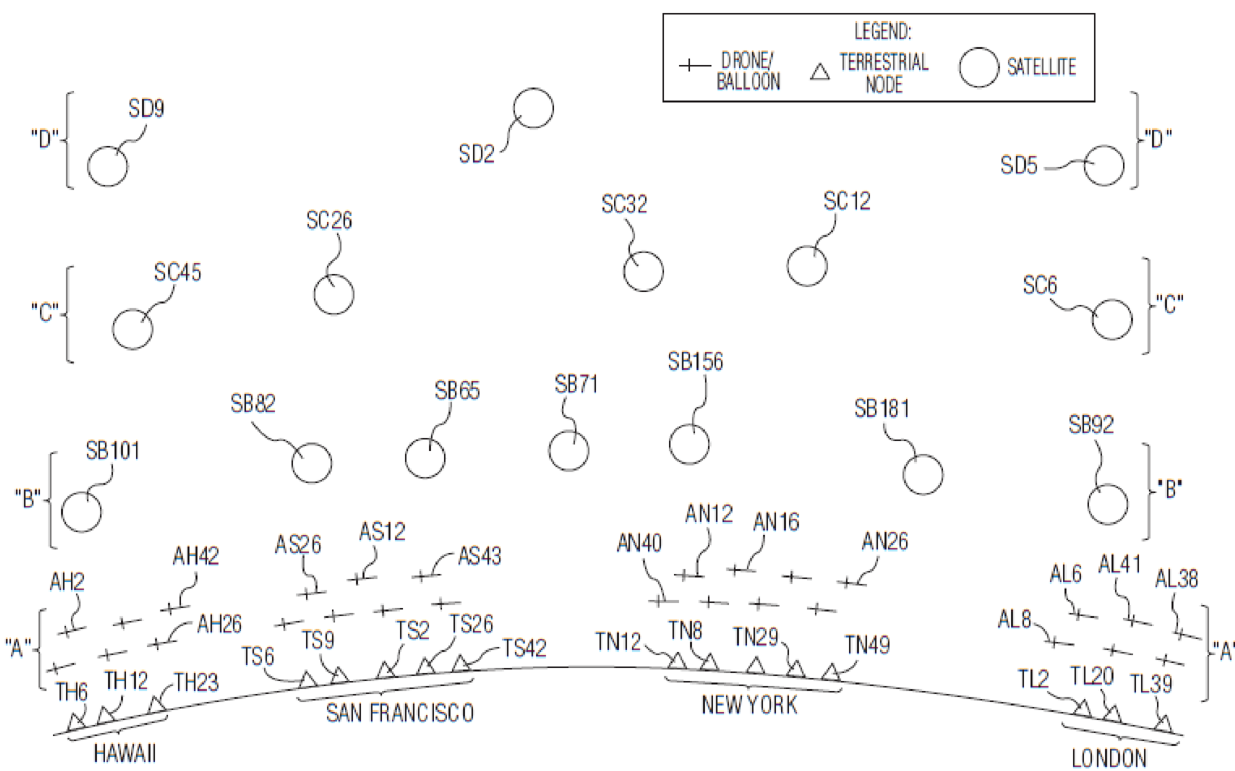

FIG. 12

System aerial nodes occupy respective levels "A," "B," "C," and "D," generally comprising four more or less distinct layers at different altitudes. One feature of this type system is that it can employ low-altitude, non-orbiting aerial nodes (drones and/or balloons) at level A to service local clusters of terrestrial nodes TN, while automatically transitioning to higher and higher altitude satellite nodes at levels B, C and D for routes over longer and longer distances.

The aerial nodes are deployed in cohorts forming four "layers" at different altitudes:

Layer/Cohort A: Drones below an altitude 400 ft., or balloons, drones and/or airships at altitudes of 10–20 miles.

Layer/Cohort B: Satellites at altitudes of 200–400 miles, but preferably below 250 miles. These satellites can be constructed as discussed above in Family G to reduce aerodynamic drag.

Layer/Cohort C: Satellites at 800–1000 miles. These satellites may require means to maintain them in orbit, or in an alternate embodiment this layer can be omitted.

Layer/Cohort D: Satellites orbiting above 2,000 miles. In some applications, geostationary satellites may be the preferred manner of providing this layer.

An essential characteristic of this system is that it employs a protocol in which the highest layer used for carrying any particular routing message is based on a postal zip code paradigm. The manner in which routing is accomplished is beyond the scope of this White Paper, but it uses the "spanning tree" approach introduced in Family E for satellites deployed at the same altitude. The '796 publication applies this approach in a unique way that allows the satellites themselves to create three-dimensional spanning tress connecting ground stations via optimal radio links over multiple layers if necessary.

In the embodiment based on Figure 12 local area transmissions are accomplished solely in the drone/balloon layer A, as described in paragraphs 0167–0169 of the '796 publication. These routes can serve particular cities, as suggested by Figure 12, and routing is accomplished largely in the manner as has been described above and in White Paper No. 3. The considerably more complex process for creating routes for which the "zip code" requires transitioning to a higher layer is described in the '796 publication in paragraphs 0170–0183.

This hybrid routing protocol takes advantage of the increased signal strength provided by drone/balloon links, as discussed above in Family G, while also supporting worldwide communications via orbiting satellites. A similar signal strength advantage is available even to users in locations with no drones or balloons, such as on a ship at sea, where route creation can start at low-altitude layer B.

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