(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 December 2020 (17.12.2020)

WIPO | PCT

(10) International Publication Number
WO 2020/251635 A4

(51) International Patent Classification:
G01S 19/41 (2010.01) *G01S 19/14* (2010.01)
G01S 19/07 (2010.01) *H04B 7/185* (2006.01)

(21) International Application Number:
PCT/US2020/021687

(22) International Filing Date:
09 March 2020 (09.03.2020)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/853,398 28 May 2019 (28.05.2019) US
16/804,961 28 February 2020 (28.02.2020) US

(71) Applicant: **XONA SPACE SYSTEMS INC.** [US/US]; 804 W. College Avenue, Marquette, Michigan 49855 (US).

(72) Inventors: **REID, Tyler Gerald René**; 1990 Dunbar St. Apt 205, Vancouver, British Columbia V6R 3M3 (CA). **GUNNING, Kazuma**; 435 Cervantes Road, Cottage, Portola Valley, California 94028 (US). **PERKINS, Adrien Louis Henry**; 440 Ravenswood Avenue, Apt. 3, Menlo Park, California 94025 (US). **NEISH, Andrew Michael**; 638 Oneida Drive, Sunnyvale, California 94087 (US).

(74) Agent: **STUCKMAN, Bruce**; Garlick & Markison, 100 Congress Avenue, Ste. 2000, Austin, Texas 78701 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,

(54) Title: SATELLITE FOR BROADCASTING HIGH PRECISION DATA

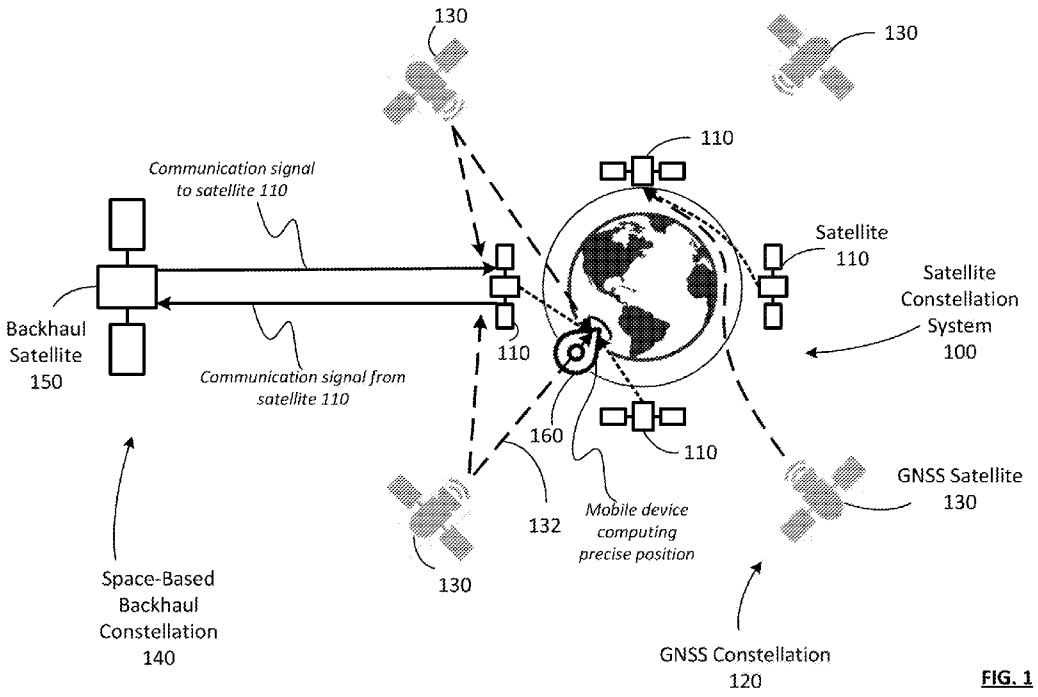

FIG. 1

(57) Abstract: A low-earth orbit (LEO) satellite includes a global positioning receiver configured to receive first signaling from a first plurality of non-LEO navigation satellites. An inter-satellite transceiver is configured to send and receive inter-satellite communications with other LEO navigation satellites. At least one processor is configured to execute operational instructions that cause the at least one processor to perform operations that include: determining an orbital position of the LEO satellite based on the first signaling; and generating a navigation message based on the orbital position. A navigation signal transmitter configured to broadcast the navigation message to at least one client device, the navigation message facilitating the at least one client device to determine an enhanced position of the at least one client device based on the navigation message and further based on second signaling received from a second plurality of non-LEO navigation satellites.

WO 2020/251635 A4

[Continued on next page]

OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

— *with international search report (Art. 21(3))*
— *with amended claims and statement (Art. 19(1))*

(88) **Date of publication of the international search report:**
18 February 2021 (18.02.2021)

Date of publication of the amended claims and statement:
22 April 2021 (22.04.2021)

AMENDED CLAIMS
received by the International Bureau on 02 March 2021 (02.03.2021)

CLAIMS

What is claimed is:

1. A low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO around the earth, the LEO satellite comprising:

a global positioning receiver configured to receive first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO, wherein the first plurality of non-LEO navigation satellites include four or more non-LEO navigation satellites of the constellation of non-LEO navigation satellites that are in reception range of the global positioning receiver;

a backhaul transceiver configured to receive correction data associated with the constellation of non-LEO navigation satellites and further configured to transmit radio occultation data, wherein the correction data includes orbital correction data and timing correction data associated with the constellation of non-LEO navigation satellites;

an inter-satellite transceiver configured to send and receive inter-satellite communications with other LEO navigation satellites in the constellation of LEO navigation satellites;

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

generating the radio occultation data based on the inter-satellite communications with at least one of the other LEO navigation satellites in the constellation of LEO navigation satellites;

determining an orbital position of the LEO satellite based on the first signaling and further based on based the correction data; and

generating a navigation message based on the orbital position, wherein the navigation message includes a timing signal and the orbital position associated with the LEO satellite and the navigation message further includes the orbital correction data and the timing correction data associated with the constellation of non-LEO navigation satellites; and

a navigation signal transmitter configured to broadcast the navigation message to at least one client device, the navigation message facilitating the at least one client device to determine an enhanced position of the at least one client device based on the navigation message and further based on second signaling received from a second plurality of non-LEO navigation satellites of the constellation of non-LEO navigation satellites in the non-LEO,

wherein the second plurality of non-LEO navigation satellites include four or more non-LEO navigation satellites of the constellation of non-LEO navigation satellites that are in reception range of the at least one client device.

2. The LEO satellite of claim 1, further comprising:

a non-atomic clock configured to generate a clock signal;

wherein the timing signal is generated by adjusting the clock signal based on the first signaling and further based on the timing correction data.

3. The LEO satellite of claim 1, wherein the inter-satellite communications include one-to-many transmissions between the LEO satellite and two or more of the other LEO navigation satellites in the constellation of LEO navigation satellites.

4. The LEO satellite of claim 1, wherein the constellation of non-LEO navigation satellites are associated with at least one of: a Global Positioning System of satellites, a Quasi-Zenith Satellite System, a BeiDou Navigation Satellite System, a Galileo positioning system, a Russian Global Navigation Satellite System (GLONASS) or an Indian Regional Navigation Satellite System.

5. The LEO satellite of claim 1, wherein the inter-satellite communications include at least one of: the navigation message sent to at least one of the other LEO navigation satellites in the constellation of LEO navigation satellites; radio occultation; atmospheric data generated based on radio occultation; control information associated with satellite direction; control information associated with satellite attitude; control information associated with satellite status; control information associated with satellite inter-satellite transmit/receive condition; command information associated with satellite inter-satellite transmit/receive status; command information associated with inter-satellite transmit power or frequency; control information associated with encryption; constellation integrity information relating to the health of one or more LEO navigation satellites in the constellation of LEO navigation satellites; or constellation integrity information relating to health of one or more non-LEO navigation satellites in the constellation of non-LEO navigation satellites.

6. A low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO around the earth, the LEO satellite comprising:

a global positioning receiver configured to receive first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO around the earth;

an inter-satellite transceiver configured to send and receive inter-satellite communications with other LEO navigation satellites in the constellation of LEO navigation satellites;

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

determining an orbital position of the LEO satellite based on the first signaling; and

generating a navigation message based on the orbital position; and

a navigation signal transmitter configured to broadcast the navigation message to at least one client device, the navigation message facilitating the at least one client device to determine an enhanced position of the at least one client device based on the navigation message and further based on second signaling received from a second plurality of non-LEO navigation satellites of the constellation of non-LEO navigation satellites in the non-LEO around the earth.

7. The LEO satellite of claim 6, further comprising:

a backhaul transceiver configured to receive correction data associated with the constellation of non-LEO navigation satellites;

wherein the determining the orbital position of the LEO satellite is further based on based the correction data.

8. The LEO satellite of claim 7, wherein the backhaul transceiver is configured to receive the correction data from one of: a backhaul communication satellite in geostationary orbit around the earth or a terrestrial transmitter.

9. The LEO satellite of claim 7, wherein the operations include:

generating radio occultation data based on the inter-satellite communications with at least one of the other LEO navigation satellites in the constellation of LEO navigation satellites; and

transmitting the radio occultation data via the backhaul transceiver.

10. The LEO satellite of claim 7, wherein the correction data includes orbital correction data and timing correction data associated with the constellation of non-LEO navigation satellites.

11. The LEO satellite of claim 10, wherein the navigation message includes a timing signal and the orbital position associated with the LEO satellite and the navigation message further includes the orbital correction data and the timing correction data associated with the constellation of non-LEO navigation satellites.

12. The LEO satellite of claim 11, further comprising:

a non-atomic clock configured to generate a clock signal;

wherein the timing signal is generated by adjusting the clock signal based on the first signaling and further based on the timing correction data.

13. The LEO satellite of claim 6, wherein the constellation of non-LEO navigation satellites are associated with at least one of: a Global Positioning System of satellites, a Quasi-Zenith Satellite System, a BeiDou Navigation Satellite System, a Galileo positioning system, a Russian Global Navigation Satellite System (GLONASS) or an Indian Regional Navigation Satellite System.

14. The LEO satellite of claim 6, wherein the navigation message includes correction data associated with the constellation of non-LEO navigation satellites in non-LEO around the earth, and wherein the at least one client device determines the enhanced position of the client device by applying the correction data to the second signaling.

15. The LEO satellite of claim 6, wherein the navigation message further includes a timing signal and the orbital position associated with the LEO satellite and wherein the at least one client device determines the enhanced position of the at least one client device further based on the timing signal and the orbital position associated with the LEO satellite.

16. The LEO satellite of claim 6, wherein the inter-satellite communications include correction data associated with the constellation of non-LEO navigation satellites received via at least one of the other LEO navigation satellites in the constellation of LEO navigation satellites;

wherein the determining the orbital position of the LEO satellite is further based on based the correction data.

17. The LEO satellite of claim 6, wherein the inter-satellite communications include at least one of: the navigation message sent to at least one of the other LEO navigation satellites in the constellation of LEO navigation satellites; radio occultation; atmospheric data generated based on radio occultation; control information associated with satellite direction; control information associated with satellite attitude; control information associated with satellite status; control information associated with satellite inter-satellite transmit/receive condition; command information associated with satellite inter-satellite transmit/receive status; command information associated with inter-satellite transmit power or frequency; control information associated with encryption; constellation integrity information relating to the health of one or more LEO navigation satellites in the constellation of LEO navigation satellites; or constellation integrity information relating to health of one or more non-LEO navigation satellites in the constellation of non-LEO navigation satellites.

18. The LEO satellite of claim 6, wherein the inter-satellite communications include one-to-many transmissions between the LEO satellite and two or more of the other LEO navigation satellites in the constellation of LEO navigation satellites.

19. The LEO satellite of claim 6, wherein the first plurality of non-LEO navigation satellites include four or more non-LEO navigation satellites of the constellation of non-LEO navigation satellites that are in reception range of the global positioning receiver.

20. The LEO satellite of claim 6, wherein the second plurality of non-LEO navigation satellites include four or more non-LEO navigation satellites of the constellation of non-LEO navigation satellites that are in reception range of the at least one client device.

21. A mobile device comprising:

a global positioning receiver configured to:

receive a navigation message from at least one low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO, wherein the navigation message includes correction data associated with a constellation of non-LEO navigation satellites in non-LEO; and

receive first signaling from a plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO; and

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

applying the correction data to the first signaling to generate corrected first signaling; and

generating an enhanced position of the mobile device based on the navigation message and the corrected first signaling.

22. The mobile device of claim 21, wherein the navigation message further includes a timing signal and the orbital position associated with the LEO satellite and wherein the at least one processor generates the enhanced position of the mobile device further based on the timing signal and the orbital position associated with the LEO satellite.

23. A method comprising:

receiving a navigation message from at least one low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO, wherein the navigation message includes correction data associated with a constellation of non-LEO navigation satellites in non-LEO;

receiving first signaling from a plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO;

applying the correction data to the first signaling to generate corrected first signaling; and

generating an enhanced position of a mobile device based on the navigation message and the corrected first signaling.

24. A low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO, the LEO satellite comprising:

a global positioning receiver configured to receive first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO;

an inter-satellite transceiver configured to send and receive inter-satellite communications with other LEO navigation satellites in the constellation of LEO navigation satellites;

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

determining an orbital position of the LEO satellite based on the first signaling;

determining, based on the first signaling, an error condition associated with one of the non-LEO navigation satellites of the constellation of non-LEO navigation satellites; and

generating a navigation message based on the orbital position, wherein the navigation message includes a timing signal and the orbital position associated with the LEO satellite, correction data associated with the constellation of non-LEO navigation satellites, and an alert signal that indicates the error condition associated with the one of the non-LEO navigation satellites of the constellation of non-LEO navigation satellites,

a navigation signal transmitter configured to broadcast the navigation message to at least one client device, the navigation message facilitating the at least one client device to determine an enhanced position of the at least one client device, while excluding signaling from the one of the non-LEO navigation satellites, based on the navigation message and further based on second signaling received from a second plurality of non-LEO navigation satellites of the constellation of non-LEO navigation satellites in the non-LEO.

25. A low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO, the LEO satellite comprising:

a global positioning receiver configured to receive first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO;

an inter-satellite transceiver configured to send and receive inter-satellite communications with other LEO navigation satellites in the constellation of LEO navigation satellites;

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

determining an orbital position of the LEO satellite based on the first signaling;

determining, based on the inter-satellite communications, an error condition associated with one of the other LEO navigation satellites of the constellation of LEO navigation satellites; and

generating a navigation message based on the orbital position, wherein the navigation message includes a timing signal and the orbital position associated with the LEO satellite, correction data associated with the constellation of non-LEO navigation satellites, and an alert signal that indicates the error condition associated with one of the other LEO navigation satellites of the constellation of LEO navigation satellites.

a navigation signal transmitter configured to broadcast the navigation message to at least one client device, the navigation message facilitating the at least one client device to determine an enhanced position of the at least one client device, while excluding signaling from the one of the other LEO navigation satellites, based on the navigation message and further based on second signaling received from a second plurality of non-LEO navigation satellites of the constellation of non-LEO navigation satellites in the non-LEO.

26. A low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO, the LEO satellite comprising:

a global positioning receiver configured to receive first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO;

an inter-satellite transceiver configured to send and receive inter-satellite communications with other LEO navigation satellites in the constellation of LEO navigation satellites;

a navigation signal transmitter; and

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

determining a first orbital position of the LEO satellite at a first current time based on the first signaling;

generating a plurality of first orbital position estimates of the LEO satellite for a plurality of first subsequent times associated within a first time window from the first current time;

generating, based on a curve fitting technique, a first navigation message indicating the first orbital position at the first current time and the first plurality of orbital position estimates of the LEO satellite for the first plurality of subsequent times;

broadcasting, via the navigation signal transmitter, the first navigation message to at least one client device;

determining a second orbital position of the LEO satellite at a second current time based on the first signaling, the second current time corresponding to one of the first plurality of subsequent times associated with the first time window and the second current time corresponding to one of the first plurality of orbital position estimates;

generating an error metric based a difference between the first orbital position of the LEO satellite at the second current time and the corresponding one of the first plurality of orbital position estimates;

when the error metric compares unfavorable to an error threshold:

generating, based on the curve fitting technique, a second plurality of updated orbital position estimates of the LEO satellite for a second plurality of subsequent times associated within a second time window from the second current time;

generating a second navigation message indicating the second orbital position at the second current time and the second plurality of orbital position estimates of the LEO satellite for the second plurality of subsequent times; and

broadcasting, via the navigation signal transmitter, the second navigation message to the at least one client device;

when the first time window expires at a third current time without a second navigation message generated:

determining a third orbital position of the LEO satellite at the third current time based on the first signaling;

generating, based on the curve fitting technique, a third plurality of updated orbital position estimates of the LEO satellite for a third plurality of subsequent times associated within a third time window from the third current time;

generating a third navigation message indicating the third orbital position at the third current time and the third plurality of orbital position estimates of the LEO satellite for the third plurality of subsequent times and

broadcasting, via the navigation signal transmitter, the third navigation message to the at least one client device.

27. A low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO, the LEO satellite comprising:

a global positioning receiver configured to receive first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO, the first signaling including at least one first timing signal generated based on an atomic clock;

an inter-satellite transceiver configured to send and receive inter-satellite communications with other LEO navigation satellites in the constellation of LEO navigation satellites;

a non-atomic clock configured to generate a clock signal;

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

determining an orbital position of the LEO satellite based on the first signaling;

generating a second timing signal by adjusting the clock signal based on the first signaling and further based on correction data associated with the constellation of non-LEO navigation satellites; and

generating a navigation message based on the orbital position, wherein the navigation message includes the second timing signal and the orbital position of the LEO satellite and correction data associated with the constellation of non-LEO navigation satellites; and

a navigation signal transmitter configured to broadcast the navigation message to at least one client device, the navigation message facilitating the at least one client device to determine an enhanced position of the at least one client device based on the navigation message and further based on second signaling received from a second plurality of non-LEO navigation satellites of the constellation of non-LEO navigation satellites in the non-LEO.

28. A mobile device comprising:

a global positioning receiver configured to:

receive a navigation message from at least one low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO, wherein the navigation message includes correction data associated with a constellation of non-LEO navigation satellites in non-LEO;

receive first signaling from a plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO; and

receive second signaling from at least one terrestrial GPS station at a fixed location; and

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

applying the correction data to the first signaling to generated corrected first signaling; and

generating an enhanced position of the mobile device based on the corrected first signaling, the second signaling and the navigation message.

29. A method comprising:

receiving a navigation message from at least one low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO, wherein the navigation message includes correction data associated with a constellation of non-LEO navigation satellites in non-LEO;

receiving first signaling from a plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO; and

receiving second signaling from at least one terrestrial GPS station at a fixed location; and

applying the correction data to the first signaling to generated corrected first signaling; and

generating an enhanced position of a mobile device based on the corrected first signaling, the second signaling and the navigation message.

30. A low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO, the LEO satellite comprising:

a global positioning receiver configured to receive first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO;

an inter-satellite transceiver configured to send and receive inter-satellite communications with other LEO navigation satellites in the constellation of LEO navigation satellites;

a backhaul transceiver;

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

generating radio occultation data based on the inter-satellite communications with at least one of the other LEO navigation satellites in the constellation of LEO

navigation satellites, the radio occultation data indicating atmospheric conditions associated with an ionosphere and a troposphere;

transmitting the radio occultation data via a backhaul transceiver;

receiving correction data associated with the constellation of non-LEO navigation satellites, the correction data generated based in part on the radio occultation data;

determining an orbital position of the LEO satellite based on the first signaling and the correction data; and

generating a navigation message based on the orbital position; and

a navigation signal transmitter configured to broadcast the navigation message to at least one client device, the navigation message facilitating the at least one client device to determine an enhanced position of the at least one client device based on the navigation message and further based on second signaling received from a second plurality of non-LEO navigation satellites of the constellation of non-LEO navigation satellites in the non-LEO.

31. A low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO, the LEO satellite comprising:

a global positioning receiver configured to receive first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO;

an inter-satellite transceiver configured to send and receive inter-satellite communications with other LEO navigation satellites in the constellation of LEO navigation satellites in accordance with a transmit/receive status;

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

determining the transmit/receive status for the inter-satellite communications between the LEO satellite and at least one other of the other LEO navigation satellites in the constellation of LEO navigation satellites;

determining an orbital position of the LEO satellite based on the first signaling; and

generating a navigation message based on the orbital position; and

a navigation signal transmitter configured to broadcast the navigation message to at least one client device, the navigation message facilitating the at least one client device to determine an enhanced position of the at least one client device based on the navigation

message and further based on second signaling received from a second plurality of non-LEO navigation satellites of the constellation of non-LEO navigation satellites in the non-LEO.

32. The LEO satellite of claim 31, wherein the transmit/receive status for the inter-satellite communications between the LEO satellite and at least one other of the plurality of other LEO navigation satellites in the constellation of LEO navigation satellites is determined based on at least one of: a memory usage of the LEO satellite; a memory usage of the at least one other of the plurality of other LEO navigation satellites; a distance between the LEO satellite and a backhaul receiver; a distance between the at least one other of the plurality of other LEO navigation satellites and the backhaul receiver; a battery level of the LEO satellite; a different between the battery level of the LEO satellite and a battery level of the at least one other of the plurality of other LEO navigation satellites; an estimated time that the LEO satellite can generate more power; an estimated time that the at least one other of the plurality of other LEO navigation satellites can generate more power; or atmospheric data that indicates atmospheric conditions generated based on radio occultation.

33. The LEO satellite of claim 31, wherein the inter-satellite communications include at least one of: the navigation message sent to at least one of the other LEO navigation satellites in the constellation of LEO navigation satellites; radio occultation; atmospheric data generated based on radio occultation; control information associated with satellite direction; control information associated with satellite attitude; control information associated with satellite status; control information associated with satellite inter-satellite transmit/receive condition; command information associated with satellite inter-satellite transmit/receive status; command information associated with inter-satellite transmit power or frequency; control information associated with encryption; constellation integrity information relating to the health of one or more LEO navigation satellites in the constellation of LEO navigation satellites; or constellation integrity information relating to a health of one or more non-LEO navigation satellites in the constellation of non-LEO navigation satellites.

34. A low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO, the LEO satellite comprising:

a global positioning receiver configured to receive first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO;

at least one transceiver configured to send and receive inter-satellite communications with other LEO navigation satellites in the constellation of LEO navigation satellites and to receive correction data corresponding to the first signaling;

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

determining an orbital position of the LEO satellite based on the first signaling and the correction data; and

generating a navigation message based on the orbital position; and

a navigation signal transmitter configured to broadcast the navigation message to at least one client device, the navigation message facilitating the at least one client device to determine an enhanced position of the at least one client device based on the navigation message.

35. A processing system of a node communicating with a satellite constellation system comprising:

at least one receiver configured to receive at least one navigation signal from at least one first other node communicating with the satellite constellation system;

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

generating, based on the at least one navigation signal, a new navigation signal that includes a ranging signal modulated with at least one navigation message; and

at least one transmitter configured to transmit the new navigation signal for receipt by a second other node communicating with the satellite constellation system, the new navigation signal facilitating the second other node to determine a position of the second other node.

36. The processing system of claim 35, wherein the operations further include:

generating, based on the at least one navigation signal, at least one of: a position of the node, or timing data for the node;

wherein the new navigation signal is generated based on the at least one of: the position of the node, or the timing data for the node.

37. The processing system of claim 35, wherein the at least one first other node is implemented as at least one low-earth orbit (LEO) satellite of a constellation of LEO satellites.

38. The processing system of claim 37, wherein a first other processing system of one LEO satellite of the at least one LEO satellite transmitted one navigation signal included in the at least one navigation signal based on the one LEO satellite:

receiving first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO;

receiving correction data corresponding to the first signaling;

determining an orbital position of the one LEO satellite based on the first signaling and the correction data; and

generating the one navigation signal based on the orbital position.

39. The processing system of claim 35, wherein a second other processing system of the second other node is configured to generate and transmit another new navigation signal based on the new navigation signal transmitted by the node.

40. The processing system of claim 35, wherein the new navigation signal is received by a plurality of second other nodes that includes the second other node based on broadcasting of the new navigation signal by the at least one transmitter.

41. The processing system of claim 35, wherein the new navigation signal is generated based on at least one of: the least one navigation message included in the at least one navigation signal, timing data included in the at least one navigation signal, a position of the at least one first other node included in the navigation signal; or the ranging signal of the navigation signal.

42. The processing system of claim 35, wherein the processing system further comprises a global positioning receiver configured to receive first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO, and wherein generating the new navigation signal is further based on the first signaling.

43. The processing system of claim 35, wherein the node is implemented as a low-earth orbit (LEO) satellite of a constellation of LEO satellites, wherein the operations further include generating a position of the node based on the at least one navigation signal, and wherein the position indicates an orbital position of the LEO satellite.

44. The processing system of claim 35, wherein the node is implemented as a backhaul satellite in one of: a medium earth orbit (MEO) and/or a geostationary orbit (GEO).

45. The processing system of claim 35, wherein one other node of the at least one first other node is implemented as a stationary infrastructure node.

46. The processing system of claim 45, wherein another processing system of the one other node is installed at a top of a building.

47. The processing system of claim 35, wherein the node is implemented as a client device, and wherein the second other node is implemented as another client device.

48. The processing system of claim 47, wherein the operations further include generating, based on the at least one navigation signal, at least one of: a position of the node, or timing data for the node, and wherein the node further comprises:

a display device configured to display the at least one of: the position of the node or the timing data for the node.

49. The processing system of claim 48, wherein the client device is one of: a mobile device, a cellular device, or a wearable device.

50. The processing system of claim 35, wherein the node is implemented as a vehicle, and wherein the second other node is implemented as a second vehicle.

51. The processing system of claim 50, wherein the vehicle is an autonomous vehicle or a highly automated vehicle, and wherein the operations further include utilizing the at least one navigation signal for precision autonomy.

52. The processing system of claim 51, wherein the at least one first other node includes at least one of: at least one stationary infrastructure node, or at least one third vehicle.

53. The processing system of claim 35, wherein the processing system further comprises at least one memory that stores application data corresponding to a service of the satellite constellation system, and wherein the operational instructions are executed by the at least one processor based on execution of the application data.

54. The processing system of claim 35, wherein generating the new navigation signal includes changing an encryption state from the encryption state of the at least one navigation signal received from the at least one first other node.

55. The processing system of claim 35, wherein the at least one navigation signal is received from the at least one first other node via a first schema, and wherein the new navigation signal is transmitted via a second schema that is different from the first schema.

56. A method comprising:

receiving at least one navigation signal from at least one first other node communicating with a satellite constellation system;

generating a new navigation signal based on the at least one navigation signal; and

transmitting the new navigation signal for receipt by a second other node communicating with the satellite constellation system, the new navigation signal facilitating the second other node to determine at least one of: timing data based on the new navigation signal, or a position of the second other node based on the new navigation signal.

57. A mobile device comprising:

a receiver configured to:

receive a set of navigation signals from a set of low-earth orbit (LEO) satellites of a constellation of LEO navigation satellites in LEO, wherein each of the set of navigation signals is transmitted by a corresponding one of the set of LEO satellites based on the corresponding one of the set of LEO satellites:

receiving first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO;

receiving correction data corresponding to the first signaling;

determining an orbital position of the one LEO satellite based on the first signaling and the correction data; and

generating the each of the set of navigation signals based on the orbital position; and

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

generating at least one of: timing data based on the set of navigation signals, or a position of the mobile device based on the set of navigation signals.

58. The mobile device of claim 57, wherein the set of navigation signals are received from a set of at least four LEO satellites of the constellation of LEO navigation satellites.

59. A method comprising:

receiving a set of navigation signals from a set of low-earth orbit (LEO) satellites of a constellation of LEO navigation satellites in LEO, wherein each of the set of navigation signals is transmitted by a corresponding one of the set of LEO satellites based on the corresponding one of the set of LEO satellites:

receiving first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO;

receiving correction data corresponding to the first signaling;

determining an orbital position of the one LEO satellite based on the first signaling and the correction data; and

generating the each of the set of navigation signals based on the orbital position; and

generating at least one of: timing data based on the set of navigation signals, or a position based on the set of navigation signals.

60. The method of claim 59, wherein the set of navigation signals are generated by the set of LEO satellites with encryption, and wherein the position is implemented as a secure position solution with encryption based on the set of navigation signals being generated with encryption.

61. A method comprising:

receiving a navigation signal from at least one low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO, wherein the navigation signal includes correction data associated with a constellation of non-LEO navigation satellites in non-LEO;

receiving first signaling from a plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO;

applying the correction data to the first signaling to generate corrected first signaling; and

generating enhanced timing data based on the navigation signal and the corrected first signaling.

62. A client device comprising:

at least one receiver configured to:

receive first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO; and

receive a navigation signal from at least one low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO, wherein the navigation signal includes correction data associated with a constellation of non-LEO navigation satellites in non-LEO;

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

applying the correction data to the first signaling to generate corrected first signaling; and

generating enhanced timing data based on the navigation signal and the corrected first signaling.

63. The client device of claim 62, wherein the client device has a known static position, and wherein the operations further include:

generating a new navigation signal based on the enhanced timing data and the known static position of the client device; and

transmitting the new navigation signal for receipt by at least one other client device, the new navigation signal facilitating the at least one other client device to determine a position of the at least one other client device.

64. The client device of claim 63, wherein the at least one other client device includes: at least one mobile device or at least one vehicle.

65. A low-earth orbit (LEO) satellite of a constellation of LEO navigation satellites in LEO, the LEO satellite comprising:

a global positioning receiver configured to receive first signaling from a first plurality of non-LEO navigation satellites of a constellation of non-LEO navigation satellites in non-LEO;

at least one transceiver configured to send and receive inter-satellite communications with other LEO navigation satellites in the constellation of LEO navigation satellites and to receive correction data corresponding to the first signaling;

at least one processor configured to execute operational instructions that cause the at least one processor to perform operations that include:

determining state data for the LEO satellite based on the first signaling and the correction data; and

generating a navigation signal based on the state data; and

a navigation signal transmitter configured to broadcast the navigation signal to at least one client device, the navigation signal facilitating the at least one client device to determine, based on the navigation signal, at least one of: enhanced state data or enhanced timing data.

Statement under Article 19(1)

The claims as amended in the present application are believed to have novelty, an inventive step and industrial applicability, and such an indication is respectfully requested in the issuance of the International Preliminary Report on Patentability. It is respectfully requested that the Examiner call or email the undersigned if clarification is needed on any matter within this Amendment.