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A Crowdsourced GNSS and PPP Reference Network

Steve Malkos

Frank van Diggelen

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ABSTRACT

Due to its requirements for well-positioned base stations and lengthy times-to-first-fix, the Precise Point Positioning (PPP) techniques for decimeter positioning haven't found widespread application in navigation in smartphones. In principle, a global network of PPP base stations can provide decimeter-level accuracy to various positioning applications, including smartphone-based navigation. However, a global network of PPP base stations that can monitor and gather satellite information is expensive to build and maintain. This disclosure describes a crowdsourced, dense, PPP network and ephemeris-coverage map that can enable GNSS chipsets (e.g., utilized in smartphones and other mobile devices) to obtain decimeter-level positioning accuracy.

KEYWORDS

- Precise Point Positioning (PPP)
- PPP network
- Global Navigation Satellite System (GNSS)
- Global Positioning System (GPS)
- Ephemeris
- PPP base station
- PPP rover
- Positioning accuracy
- Carrier-phase tracking
- Crowdsourcing

BACKGROUND

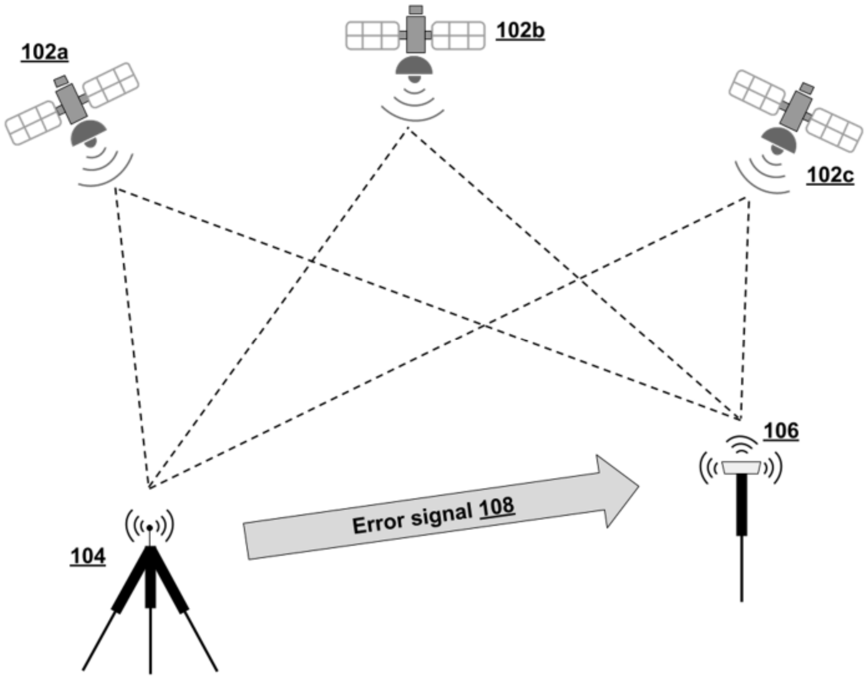

Fig. 1: Differential GNSS and PPP

Fig. 1 illustrates Precise Point Positioning, a technique that can produce decimeter-level positioning accuracy. Satellites (102a-c) from a global navigation satellite system (GNSS) transmit positioning signals, which are received by a fixed, positioning base station (104), also known as reference station. The positioning base station (not to be confused with the base stations of cell-phone networks) uses the satellite signals and its known position to compute the errors on the satellite signals.

A rover (106) is a mobile positioning unit that can be moved to any point whose position is to be determined. The rover uses GNSS to determine its position. The base station transmits an error signal (108) to the rover. The rover uses the error signal to correct its GNSS-determined position to achieve higher accuracy. So long as the base station and the rover are within reasonable distance of each other, e.g., 10-15 km, an initial error in the rover's position can be substantially corrected by the base station.

Due to the requirement of well-positioned base stations the PPP technique has found applications in surveying and civil engineering but is not widespread in consumer use cases. In principle, a global network of GNSS base stations can provide decimeter-level accuracy to all positioning applications including smartphone-based navigation or other applications. However, a global network of base stations that can monitor and gather satellite information is expensive to build and maintain.

DESCRIPTION

This disclosure describes techniques for a crowdsourced, dense network and ephemeris-coverage map that can enable GNSS chipsets (e.g., smartphones) to obtain decimeter-level positioning accuracy.

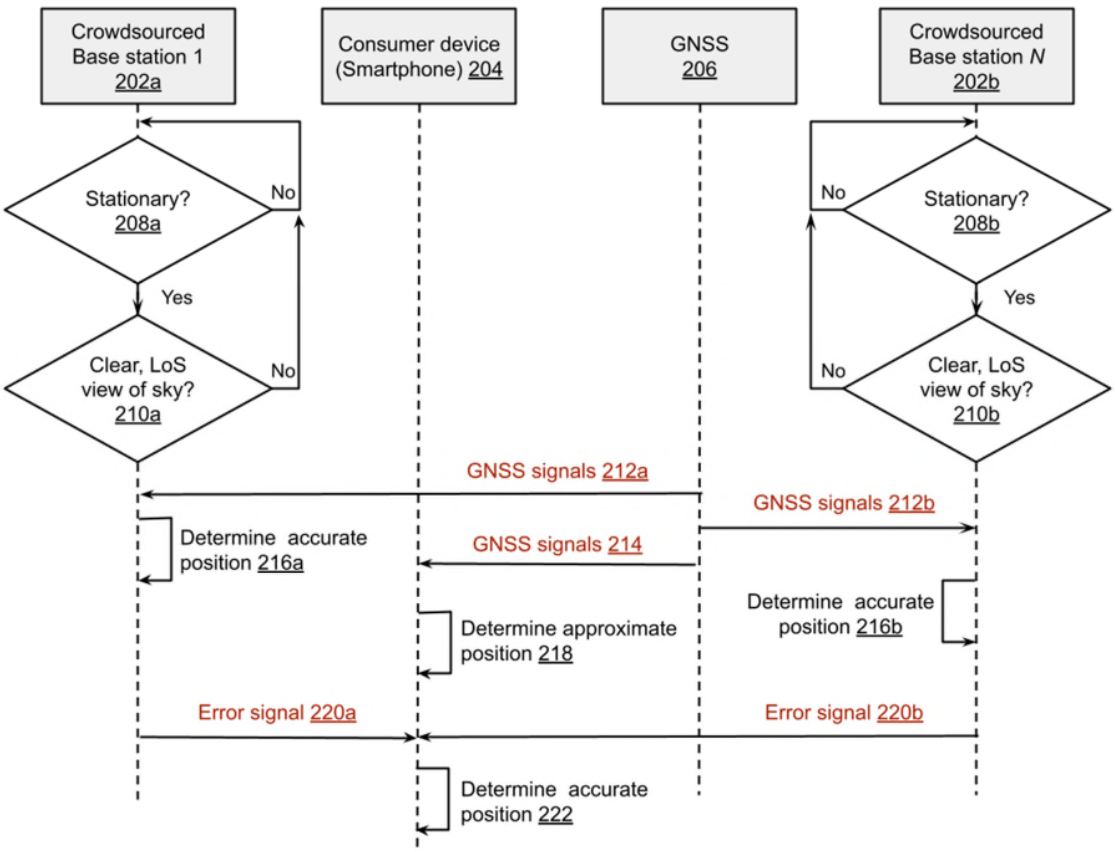

Fig. 2: Crowdsourced GNSS and PPP reference network

Per the techniques, illustrated in Fig. 2, with specific user permission, a customer device, e.g., an automotive GPS unit, can serve as a base station from which information is obtained via crowdsourcing. An automotive GPS unit, when permitted by the user, can advantageously serve as a crowdsourced base station because of the following reasons:

- Cars have relatively large batteries, enabling the collection of ephemeris when the vehicle is turned off.
- Cars have relatively large GNSS antennas, adding to positioning accuracy.
- Cars are widespread and common, they are often stationary (parked) for large portions of the day, and there is always a percentage of parked cars at any given time that have clear views of the sky. Such parked cars with clear, line-of-sight (LoS) views of the sky can activate their automotive GPS to perform the tasks of ephemeris collection and accurate self-positioning.

Each of crowdsourced base stations 1 through *N* (202a-b), which can be, as explained before, automotive GPS units, determines if it is stationary (208a-b). By referring to maps of their present (stationary) location, each crowdsourced base station can determine if it has a clear, LoS view of the sky (210a-b). The maps can include three-dimensional topographic data, e.g., the presence and heights of nearby buildings, foliage, terrain, etc., such that the crowdsourced base stations can determine if they are in an open sky (building-free / no signal blockage) environment.

Each crowdsourced base station that is stationary with a clear, LoS view of the sky, receives and processes signals (212a-b) from one or more GNSS (206) and utilizes the signals to determine its position accurately (216a-b), e.g., to decimeter-level. The crowdsourced base stations can determine their own accurate positions using lengthy averaging, carrier-phase tracking, and/or other standard techniques.

A consumer device that is moving, e.g., a smartphone or other mobile device (204), receives and processes GNSS signals (214) to determine its own position approximately (218), e.g., to a three-meter accuracy. The moving consumer device also receives error signals (220a-b) from a network of nearby crowdsourced base stations and utilizes the error signals to determine its position to high, e.g., decimeter-level, accuracy (222).

The consumer device that is in motion can advantageously have certain features to enable the use of error signals received from the nearby network of crowdsourced base stations to compute its own position to decimeter-level accuracy. For example, it can have dual-band GNSS (L1 and L5).

In this manner, the techniques of this disclosure enable the rapid deployment of a global dense reference network (GDRN), e.g., a network of base stations (satellite reference network) to collect the ephemeris used for assisted-GNSS and decimeter-level PPP positioning. Being crowdsourced, the GDRN (also known as the worldwide reference network, WWRN) and the PPP network can be set up quickly and maintains itself continuously, e.g., as certain base stations go out of service (e.g., due to their becoming non-stationary), other base stations fill in.

The described crowdsourced base station network can support various applications, e.g., navigation; maintaining lane fidelity in self-driving cars; accurate yet inexpensive surveying, e.g., by do-it-yourself landowners not trained as professional surveyors; etc.

CONCLUSION

This disclosure describes a crowdsourced, dense, PPP network and ephemeris-coverage map that can enable GNSS chipsets (e.g., utilized in smartphones and other mobile devices) to obtain decimeter-level positioning accuracy.

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