# First Proof That Geographic Location on Deployed Fiber Cable Can Be Determined by Using OTDR Distance Based on Distributed Fiber Optical Sensing Technology

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**Abstract:** We demonstrated for the first time that geographic locations on deployed fiber cables can be determined accurately by using OTDR distances. The method involves vibration stimulation near deployed cables and distributed fiber optical sensing technology.
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## 1. Introduction

Telecom carriers and network service providers have built huge scale optical fiber infrastructures to support Internet. It is estimated that more than three million sheath miles of optical fiber cables have been deployed in the United States. [1] To maintain the integrity of deployed fiber infrastructures, network service providers' operation teams need often to repair fiber cable problems in field, such as fiber cut, high loss splice points, tightly bending points etc. When there is a fiber fault in field, an operation team usually uses an optical time-domain reflectometer (OTDR) to measure the distance of the fault location from the central office (CO) where the OTDR sits. After knowing the OTDR distance, however, the operation team is still not able to determine the fault geographic location accurately since complicated fiber cable deployment paths and fiber slacks reserved along the cable line make the OTDR distance is normally much longer than the actual driving distance from the CO to the fault location with a range of 15 – 20% difference typically. So far there is no existing method to determine the fault location on geographic map based on OTDR measurements. A lot of guesswork is involved in finding the exact locations of fiber faults in operation teams' daily practice.

In this paper, we report the first proof that geographic locations on deployed fiber cables can be determined by mapping OTDR distances to a geographic map using distributed fiber optical sensing technology. The method has 4-m accuracy for buried cables and is able to locate each pole exactly for aerial cables. With this method, network operation teams will be able to pinpoint a fiber fault quickly and accurately base on an OTDR measurement. This solution will greatly enhance operation teams' work efficiency when searching and fixing fiber problems in field.

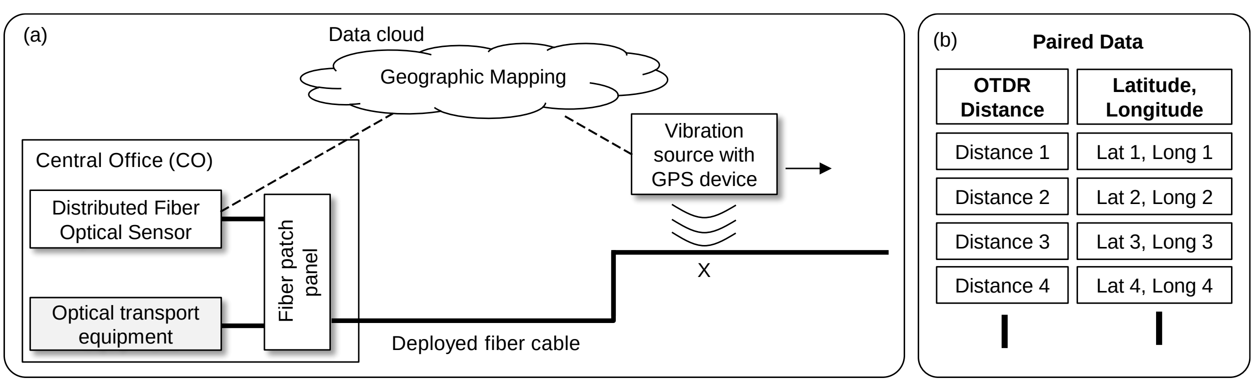


Fig 1. The method to determine the latitude and longitude of deployed fiber cable (a) and OTDR distance and latitude-longitude paired data (b).

## 2. The Novel "Cable Lat-Long" Method

We have invented a novel method to determine any location on a deployed fiber cable accurately. The method can be called "the method to determine latitude and longitude of any location on deployed fiber cable" or briefly "the cable lat-long method". The method is illustrated in Fig 1(a). It includes several key components. (1) Use a portable vibration source to move along the path on which the cable is deployed to stimulate tiny localized vibration of the fiber inside the deployed cable, as an exemplary location "X" shown in Fig 1(a). (2) A GPS (Global Positioning System) device, which moves together with the vibration source, sends the latitude and longitude of its current location to a data cloud.

(3) A distributed fiber optical sensor that sits in a CO and is connected to the OSP (outside plant) cable, which carries telecom data traffic sent by optical transport equipment, to detect the OTDR distance between the CO and the location, where the vibration source is simulating the cable at that moment. The fiber sensing system reported the OTDR distance data measured at that moment to the cloud as well. (4) The data cloud pairs the data of GPS and OTDR distance, which are taken at the same time, and saves the paired data into a database. A GUI (graphical user interface) can be developed to show a fiber location on a geographic map based on a given OTDR distance. (5) When an operation team needs to find the location of a fiber fault on the deployed cable, they can use an OTDR at the CO to measure the distance of the fault first, then input the distance information into the database, and the exact location with coordinate of the fault will be displayed on a geographic map on the GUI. The technology of the distributed fiber optical sensing system has been reported previously [2-4], when using the technology to detect motor traffic with deployed telecom fiber cable was demonstrated. The technology is based on detection of dynamic phase characteristics of Rayleigh backscattering, therefore, the measured distance of a fiber vibration event on the cable is the same as an OTDR distance measured with a normal OTDR test equipment.

**3. Field Trial Set-Up and Trial Procedure**

Figure 2 shows the field trial set-up for the "cable lat-long" method. A deployed fiber cable route, which belongs to Verizon metro network in Dallas, Texas area, is chosen to perform the trial. The fiber route is about 12 km long and its deployment path is shown in Fig 2(a). A portable mechanical vibration source was used to stimulate tiny vibration of fiber in the deployed cable. It was powered by a portable generator, as shown in Fig 2(b). A GPS device was used to record the latitude and longitude of the current location. A fiber sensing system was installed in the Verizon central office to measure the OTDR distance of the stimulated localized fiber vibration event in field at a particular location, as shown in Fig 2(c).

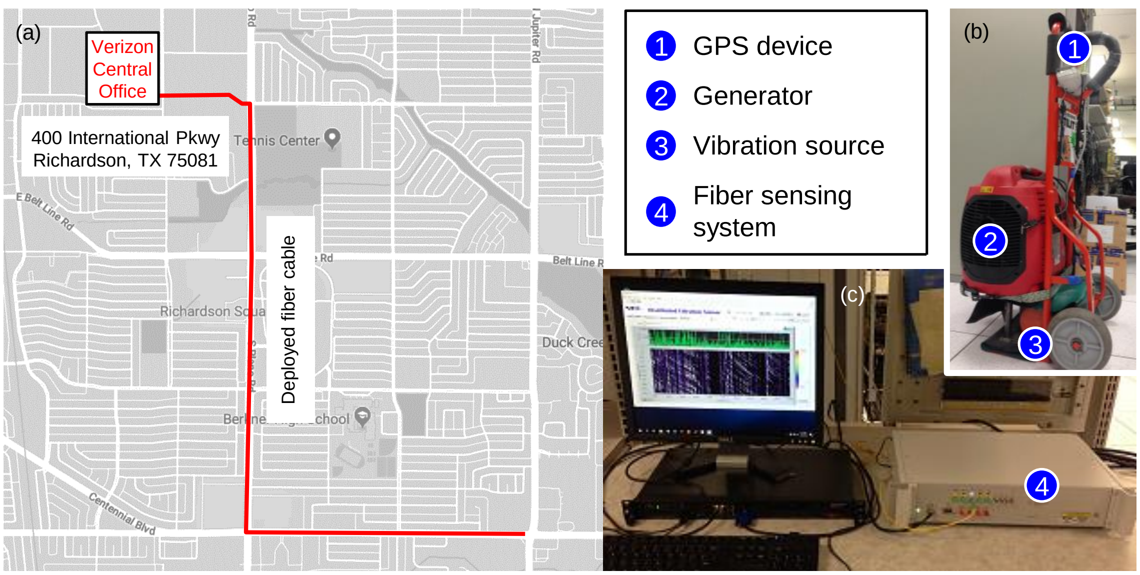


Fig 2. Fiber route selected for the trial (a), the mechanical vibration source with GPS (b), and the fiber sensing system (c).

During the trial, the vibration source was towed along the path of the deployed fiber cable. The fiber cable route is composed of buried cable and aerial cable sections. For the buried cable sections, the cable is about 36-48 inches deep underground. For the aerial cable sections, the cable is installed on utility poles. The vibration source moved along the cable route within a range of 6 feet from the cable in horizontal direction for the buried cable sections. For the aerial cable sections, the vibration source moved pole-to-pole along the straight lines linking adjacent poles. The GPS device was used to record the latitude and longitude data for the current location of the vibration source. At the same time, the fiber sensing system in the central office recorded the measured OTDR distance of the stimulated vibration event near the deployed cable. After all data of the trial route were collected, the GPS data and the OTDR data were paired and saved into a database for future use.

**4. Trial Results**

During the trial we have collected more than 2,500 pairs of latitude-longitude data and OTDR distance data for a total length of 12-km deployed fiber cables. Examples of the collected and paired data are shown in Fig 3(a). The location accuracy of 4 m was obtained by the fiber sensing system for both buried cable and aerial cable sections. For the aerial cable sections, the locations of the poles were determined and the locations of the cable segment between two neighboring poles were estimated based the locations of the two poles. Practically, for aerial cables, as long as the location of poles can be determined, operation teams should be able to find fiber faults between poles easily.

Figure 3(b) shows an OTDR curve and Fig 3(c) shows a mapping of OTDR distance to a geographic location on a Google map. A user friendly GUI has been developed for demonstration of the “cable lat-long” method with the data collected during this field trial. The GUI simulates the real environment in which how a field operation team uses the paired data to find a cable location quickly and accurately. As shown in Fig 3(b), for a given OTDR distance, the GUI provides the corresponding geographic location on the Google map immediately. The GUI and the database are now available for potential users of the new method to play with it.

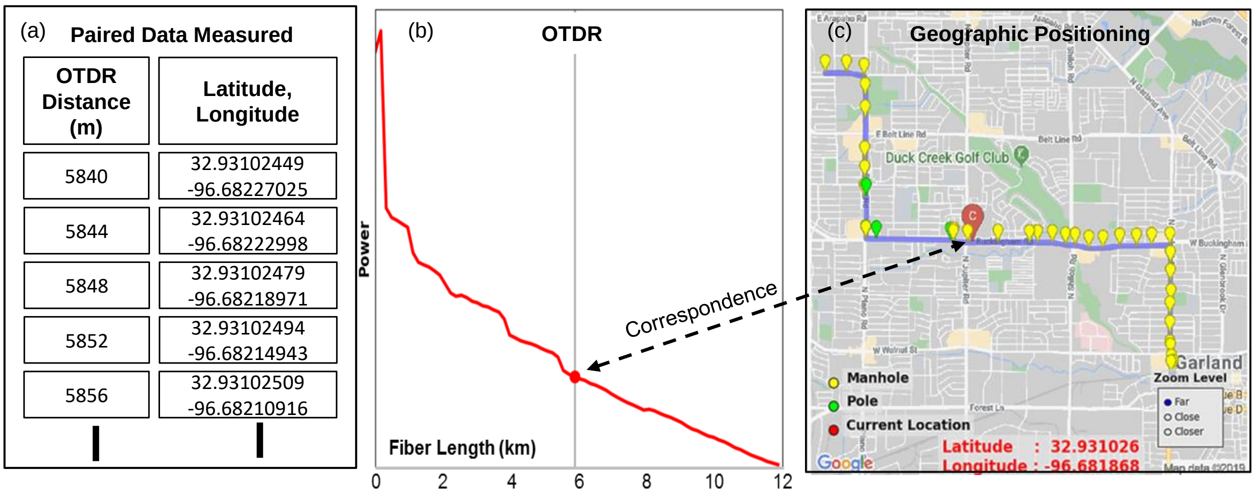


Fig 3. The trial results. Examples of measured and paired GPS data and OTDR distance data (a), and a GUI which shows correspondence between an OTDR distance on an OTDR curve (b) and its mapped geographic location on a Google map (c).

## 5. Discussions

This new “cable lat-long” method is easy to implement by network service providers. For each deployed fiber cable, it only needs collect and pair its latitude-longitude data and corresponding OTDR distance data once. When a deployed fiber cable has some changes due to city constructions or other reasons, only the data of the impacted cable needs to be re-mapped while data of other fiber cables are still intact. A robotic vibration source may be used to crawl fiber cable paths and save GPS data automatically. Additionally, an optical switch may be used to switch the fiber sensing system to different fiber cables ended at a CO and record OTDR distance data automatically as well. Once a “cable lat-long” database is generated, operation teams can pinpoint fiber fault locations much faster and more accurate than they can do today.

## 6. Conclusions

For the first time we demonstrated that a geographic location on a deployed fiber cable can be determined by using a normal OTDR curve based on distributed fiber optical sensing technology. According to our newly developed “cable lat-long” method, a movable mechanical vibration source is used to stimulate tiny vibration of fiber in deployed cable along a cable route and a fiber sensing system at a central office is used to detect the vibration. Latitude and longitude of the current location of the vibration source are measured with a GPS device and an OTDR distance is detected at the CO at the same time. The collected GPS location data and corresponding OTDR distance data are paired and saved into a database. With the database, operation teams of telecom network service providers are able to determine the geographic location of a fiber fault in a deployed fiber network quickly with a high level of accuracy. This field trial proves that this new method has a great potential to improve network operation efficiency in near future.

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