January 11, 2019

CONNECTIVITY ASSESSMENT SURVEY FOR TECHNOLOGY EMERGENCY RESPONSE (CASTER)

Rakesh Bharania

Chandler Johnson

Dustin Li

CONNECTIVITY ASSESSMENT SURVEY FOR TECHNOLOGY EMERGENCY RESPONSE (CASTER)

AUTHORS:
Rakesh Bharania
Chandler Johnson
Dustin Li

ABSTRACT

Disasters such as hurricanes, earthquakes, and tsunamis often cause widespread communication outages, and there is a need to quickly assess which areas have been impacted so that teams such as Tactical Operations can optimize the delivery and installation of emergency communications infrastructure. By placing a software defined radio (SDR) in low earth orbit on a satellite and processing the data to geolocate radio frequency (RF) signals, heat maps may be generated depicting "ground truth" RF changes, providing timely and accurate data to inform decision-making for emergency communications deployments. This, in turn, will serve as a force multiplier, amplifying the positive impact that can be made by first responders in disasters.

DETAILED DESCRIPTION

Telecommunications infrastructure is critical in a disaster, allowing first responders to contact team members and request resources, and enabling affected populations to locate family members and communicate their needs to public safety officials. Tactical Operations (TacOps) is a team dedicated to providing aid in the form of data, voice, and radio infrastructure to fill communications gaps immediately following an acute disaster. Often hurricanes will damage cell towers, earthquakes and mudslides will sever landlines, and power grids will fail causing widespread communications infrastructure outages. In order to maximize effectiveness of aid response and restoration, there is a need to quickly assess the state of the preexisting infrastructure, and discover which services are degraded in order to determine where aid can be applied most effectively. However, with the tools currently available, it is difficult to determine where service has been taken offline without physically visiting each location. Considering the large geographic impact of disasters such as hurricanes in remote areas, such an undertaking is challenging or impossible to manage.

Present techniques provide an improved way of assessing infrastructure and services after a disaster. Here, a satellite or constellation of satellites is configured to monitor large geographic areas for a broad spectrum of RF emissions, to determine where common RF-based communications, including cellular and Wi-Fi, have been damaged or destroyed. Low earth orbit satellites can be launched with orbital patterns covering the vast majority of the world's population, as well as with equipment and network platforms to gather data, making them well-suited to gather communications infrastructure assessment data globally. A tool may be built and configured to display global radio frequency "heat maps" via an SDR and an antenna array system mounted on the ISS. This configuration will enable decision-makers in humanitarian aid teams, governments, communications service providers, and others to determine the impact of an event on wireless RF communications by comparing current readings to past readings in the same location.

In particular, SDR technology may be used to survey a city or region affected by a natural disaster and assess the availability of major RF-based communications and telecommunications services including AM/FM radio, television, cellular networks, and Wi-Fi. This technology will continue to be driven by increasing technological dependency and urbanization of societies all around the world, and the occurrence and probable increase of major disasters.

The components on the satellite or satellite constellation will comprise an antenna array and one or more SDRs, including any other affiliated hardware and software. In some aspects, the system may use existing data backhaul or a purpose-built data link to a ground-based database, which will house the data from the satellite components. Servers to process and display the data, host the software, and manage authentication to the system will also be needed.

Frequencies that will be monitored include broadcast FM radio, Wi-Fi, cellular, ham radio repeaters, commercial/first responder radio repeaters, and aeronautical repeaters. The overall range will include frequencies from 76 MHz (lower end of FM radio) to 5875

MHz (high end of 5 GHz Wi-Fi). This range of frequencies will be scanned in near real-time, with a bandwidth covering the entire range of frequencies (at least 6 GHz) and sufficient sensitivity to detect point sources of 100 mW effective isotropic radiated power (EIRP) or greater measured at ground level. Ideally, the heat map would be sufficiently sensitive to receive transmissions from both high-powered base stations as well as client access devices, in order to help answer assessment-relevant questions such as:

- Which services are degraded?
- What level and types of services were in place before the event?
- When did the service degradation occur and how long has it been degraded?
- Where is the need for assistance?
- How large of an area does the service degradation cover?

The data points may include the date, time, GPS location, frequency, frequency signal level, and backhaul availability. The output may be a map in common GIS formats with these data points displayed as a "heat map" based on the frequency signal level, with filters for various frequency channels and bands. The map will have the greatest resolution available, ideally 3 meters or smaller for each point.

The system will be able to rapidly assess the RF spectrum over a disaster zone and produce various forms of maps in commonly used GIS formats (e.g., ESRI, Google Earth, OpenStreetMap, etc.) with enough fidelity to provide approximately 3-meter resolution. These maps could then be compared to population densities, location of critical infrastructure (government offices, hospitals, and others) so that technology responders, telecommunications carriers, and other organizations on the ground can better target the use of Hastily Formed Networks (HFNs), mobile AM/FM radio transmissions, and other emergency telecommunication services. A web- or app-based tool may be provided to disaster response teams or other researchers that would benefit from this data.

Various operational scenarios are considered, including:

- Before/after mapping: mapping an area before a disaster hits, and then again within 72 hours post-disaster to show the difference.
- Identify gaps in connectivity relative to population densities and critical infrastructure (hospitals, airports, ports, etc.).

  - Determine whether base stations are powered and transmitting.
  - Determine whether clients are able to associate to base stations.
  - Determine whether network access/backhaul is available to the base stations and clients.
  - Determine the number of unique clients that are trying to connect.
- Validate and map restoration efforts: Is connectivity back? Recurring mapping +3/+6/+9 days, etc. should show progress of restoration.
- Identify underserved or "forgotten" areas where populations may remain cut-off from communications.
- Identify geographic population flows of clients out of disaster-affected area.
- Determine propagation of RF signals as they pass through the atmosphere to the ISS by comparing with ground-level readings.

The SDR(s) and antenna array will need power and data connectivity to the earth-bound storage database from the satellite or satellite constellation. Storage for the data output will be maintained as long as the SDR(s) are collecting data, and the data will be safely stored per modern information security standards. The database and server will need to be maintained, including software and hardware updates as well as resolving software bugs and/or hardware issues as such issues arise. The software UI and all other associated software will be updated to mitigate security flaws in the system and it will be improved as more use cases are developed or in response to feedback from the users. The authentication system must be kept up to date with the latest cryptography standards, including two-factor authentication and current cryptography algorithms.

In summary, disasters such as hurricanes, earthquakes, and tsunamis often cause widespread communication outages, and there is a need to quickly assess which areas have been impacted so that teams can optimize the delivery and installation of emergency communications infrastructure. By placing an SDR in low earth orbit on a satellite or satellite constellation and processing the data to geolocate RF signals, heat maps may be generated depicting RF changes, providing timely and accurate data to inform decision-making for emergency communications deployments. This, in turn, will serve as a force multiplier, amplifying the positive impact that can be made by first responders in disasters.

This technology may also be used by mobile telecommunications carriers and regulatory authorities who wish to map coverage areas, gaps, the increasing access of telecommunications to developing populations, and other applications in both disaster and non-disaster areas.