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## **OPTIMIZATION OF CBRS GEOFENCE SWITCHING BY MERGING NEARBY CBSD CELLS**

### **Abstract**

To reduce the processing, memory, and data transfer overhead for a user equipment (UE) related to maintaining, monitoring, and receiving updates for a record of a large number of Citizens Broadband Radio Systems (CBRS) geofences (i.e., a CBRS geofence record) corresponding to individual Citizens Broadband Service Device (CBSD) coverage areas, a system redefines the coverage area of multiple nearby CBSDs into a single cluster and then updates the CBRS geofence record stored at a UE based on the coverage areas of such CBSD clusters rather than individual CBSD coverage areas. Each time the system receives an update to a carrier's coverage file representing CBSD coverage areas, the CBSD clusters are redefined, with a new cluster being created from the initial CBSD listed in the coverage file, and subsequent CBSDs being either added to existing CBSD clusters or being used to create new CBSD clusters.

### **Background**

The CBRS band is presently defined as the frequency band within 3500 MHz – 3700 MHz and is usable by ordinary enterprises in addition to cell carriers. When operating in the shared spectrum of the CBRS band, users with different levels of priority have access to the band, with higher priority users being protected from interference by lower priority users. Any applicable technology can be used within the CBRS band if adhering to sharing stipulations of the CBRS band.

A CBSD performs as a radio node/access point/base station within a CBRS network. A UE, such as a smartphone, handset, or Internet of Things (IoT) element, wirelessly communicates with a CBSD using the CBRS band. The CBSD operates in coordination with a

Spectrum Access System (SAS), which is a cloud-based service that manages the wireless communications of devices transmitting in the CBRS band. The SAS administrator is generally a carrier or enterprise that enforces the sharing stipulations of the CBRS band to, for example, prevent harmful interference by lower priority users to higher priority users. As such, a CBSD needs authorization from the SAS before it starts to transmit in the CBRS band.

In order for a UE to opportunistically use CBRS sparse networks (e.g., to save battery life of the UE), a CBRS modem stack of the UE is enabled only when the UE enters a CBRS network coverage area, that is, an area in which a sufficiently strong signal strength is expected to be achievable between a CBSD and a UE. Geofence switching is used to automatically activate the CBRS modem stack of the UE when the UE enters a CBRS network coverage area. As the overall number of CBSD deployments increases, a relatively large number of geofences must be defined on, and referenced by, the UE. This typically is achieved by storing geofence definitions or other representations of the geofences in the CBRS geofence record of the UE, which often results in high memory and storage utilization and thus reduces system performance.

### **Description**

In order to reduce the number of geofence definitions that must be stored at a given UE, the present system clusters CBSD coverage areas together from the individual CBSD coverage areas defined for each CBSD in a wireless carrier's coverage file. The system generates new geofence definitions based on the resulting CBSD clusters. The system loads the new geofence definitions onto new UEs during configuration of new devices as part of the device provisioning process and sends updated geofence definitions to existing UEs via an over-the-air (OTA) update or another update process. For example, the system loads CBSD-cluster-based geofence definitions relevant to the CBRS carrier for a UE to the memory of the UE at the time the

operating system is installed on the UE, then the system updates the CBSD-cluster-based geofence definitions via an OTA update. Examples of the logic and implementation of clustering algorithms used to perform such CBSD clustering are described below.

Each time a carrier's coverage file is updated, such as when a CBSD is added or removed from the carrier's coverage file, the present system redefines the CBSD clusters represented in the carrier's coverage file. For example, when redefining CBSD clusters based on an updated coverage file, the system first creates a new cluster using the first, or initial, CBSD in the coverage file. For each CBSD in the file after the first CBSD, that CBSD is either added to an existing cluster, or the system creates a new cluster using that CBSD. For example, for each CBSD (the 'current CBSD') after the first, the system identifies a cluster (i.e., of the clusters that have been created for the carrier's coverage file so far) whose near edge is closest to the current CBSD. If the distance between the current CBSD and the nearest cluster is within a predetermined threshold distance, the CBSD is added to that cluster, as described below. Otherwise, a new cluster is created with the current CBSD. The CBSD clusters defined in this process are then used to create corresponding geofence definitions, which the system sends to new or existing UEs to update the CBRS geofence records of those devices.

A new cluster is only created with one CBSD initially, with the new cluster inheriting all of the properties of that CBSD. Subsequently, other CBSDs that are within a predetermined threshold distance of the edges of the new cluster are added to the new cluster.

When adding a CBSD to an existing cluster, the area encompassed by the existing cluster is expanded to include the area encompassed by the CBSD being added. An example is shown in FIG. 1.

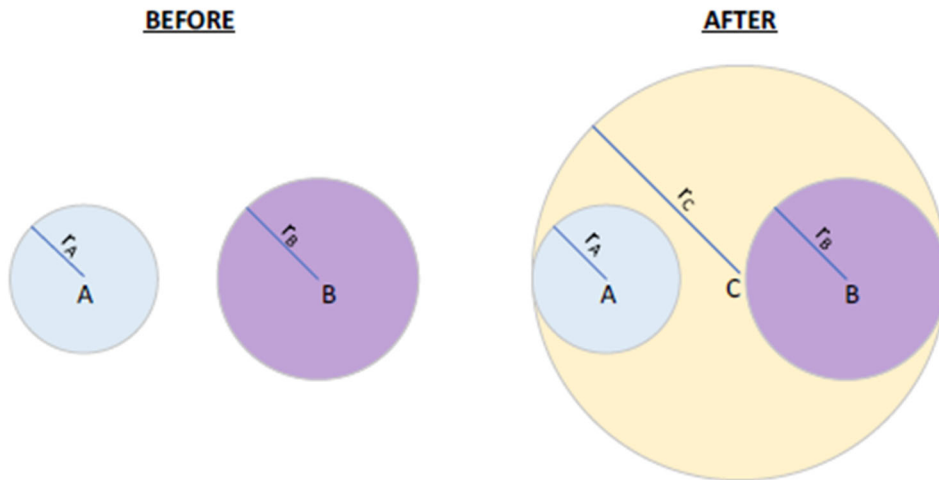


FIG. 1

FIG. 1 illustrates an example of a circle ‘A’, representing an individual CBSD coverage area, being added to an existing circle ‘B’, representing an existing CBSD cluster’s coverage area, to create a new circle ‘C’ that represents the coverage area of a new cluster coverage area that is a combination of the individual CBSD coverage area and the existing CBSD cluster coverage area. The center of the new circle ‘C’ is located at the center of the shortest line between the two farthest points of circle ‘A’ and circle ‘B’ and that has a diameter equal to the distance between the two farthest points of circle ‘A’ and circle ‘B’. Herein, the “farthest points” of circles ‘A’ and ‘B’ are defined as the pair of points of the circles ‘A’ and ‘B’ that has the greatest distance between the points compared to any other pair of points of the circles ‘A’ and ‘B’.

Generally, the carrier’s coverage file defines latitude/longitude coordinates and a radius for each CBSD, where the coverage area of a given CBSD is defined as a circle that is centered at the latitude/longitude coordinates, where the radius of the circle is the radius of the CBSD’s coverage area. Thus, when a new CBSD cluster is defined, it inherits the latitude/longitude

coordinates and radius of the CBSD that was used to create the new CBSD cluster. In the example of FIG. 1, when calculating the new circle ‘C’ from the circles ‘A’ and ‘B’, circle ‘A’ is defined as  $(A_{lat}, A_{lon}, r_A)$ , where  $A_{lat}$  is the latitude coordinate for the center of circle ‘A’,  $A_{lon}$  is the longitude coordinate for the center of circle ‘A’, and  $r_A$  is the radius of the circle ‘A’. Circles ‘B’ and ‘C’ are similarly defined as  $(B_{lat}, B_{lon}, r_B)$  and  $(C_{lat}, C_{lon}, r_C)$ , respectively.

In order to determine the center and radius of the circle ‘C’, the system calculates the distance between the two centers  $\|\underline{AB}\|$  in meters using the great-circle distance (i.e., orthodromic distance) between the longitudinal coordinates of circles ‘A’ and ‘B’ on the Earth’s surface. The system then calculates the distance between the far edge of circle ‘A’ and the far edge of circle ‘B’ as  $\|\underline{XY}\| = \|\underline{AB}\| + r_A + r_B$ . The system calculates the radius,  $r_C$ , of the new cluster as half of  $\|\underline{XY}\|$ . The system then calculates the coordinates of the center point of the new circle ‘C’. Since the coordinates of the farthest points X and Y are unknown, the coordinates of the centers of circles ‘A’ and ‘B’ are used instead. So, the coordinates  $(C_{lat}, C_{lon})$  of the center of the circle ‘C’ can be defined using the following set of equations:

$$\|\underline{AC}\| = r_C - r_A \quad \text{EQ. 1}$$

$$f = \frac{\|\underline{AC}\|}{\|\underline{AB}\|} \quad \text{EQ. 2}$$

$$C_{lat} = A_{lat} \times (1 - f) + B_{lat} \times f \quad \text{EQ. 3}$$

$$C_{lon} = A_{lon} \times (1 - f) + B_{lon} \times f \quad \text{EQ. 4}$$

where  $\|\underline{AC}\|$  is the distance from the center of circle ‘A’ to the center of circle ‘C’, and  $\|\underline{AB}\|$  is the great-circle distance from the center of circle ‘A’ to the center of circle ‘B’.

Once the coordinates of the center of the circle ‘C’ are calculated, the system defines other properties for the new cluster corresponding to the circle ‘C’. In one example, the CBSD

identifier ‘cbsd\_id’ is set to that of the first CBSD that was added to the cluster. In another example, an elevation parameter ‘elevation\_meters’ is defined for the new cluster as the average of the elevation of all CBSDs in the cluster. In another example, the average of the elevation of all CBSDs in the cluster can be calculated using the following running average equation:

$$\text{new average} = \text{current average} + \frac{\text{new value} - \text{current average}}{\text{current number of items} + 1} \quad \text{EQ. 5}$$

In another example, the bands of the new cluster are defined as the union of all bands of the CBSDs in the cluster. In another example, a set of accessible carrier identifiers, ‘accessible\_carrier\_ids’, are defined as the union of all of the accessible carrier identifiers of the CBSDs in the cluster.

As indicated above, once the entire carrier coverage file has been processed by the system to define CBSD clusters, the system sends corresponding geofence definitions to new and existing UEs to update the respective CBRS geofence records stored at those devices.

It should be understood that alternative approaches can be used to perform the method of CBSD clustering described above. In one example alternative approach, the system could alternatively define CBSD clusters using K-means clustering. While K-means clustering is a vetted algorithm, it tends to be slower and more difficult to adapt than the present approach described above.

As another example alternative approach, instead of calculating the center of a new CBSD cluster as a central point between the farthest points of the new CBSD’s coverage area and the existing cluster’s coverage area and being centered, the system could instead calculate the center of the new CBSD cluster as the average of all CBSD centers represented in the new CBSD cluster. While calculating a new CBSD cluster center as the average of CBSD centers

within the cluster is generally straightforward and readily implemented, such an approach can lead to excessive non-covered space in the coverage area of the new CBSD cluster.

## References

*System and Method for Enabling Interference-awareness for LTE Operation in Unlicensed Spectrum*, U.S. Patent Application Pub. No. 20190036629, filed July 19, 2018, the entirety of which is hereby incorporated by reference.

*Electronic apparatus and method used in wireless communications, and computer readable storage medium*, PCT Patent Application Pub. No. 2019129169, filed December 28, 2018, the entirety of which is hereby incorporated by reference.

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