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EXTERNAL INTERFERENCE MANAGEMENT ON RADIO ACCESS NETWORK TECHNOLOGY

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ABSTRACT

The embodiments disclosed herein relate to automatically detecting and managing external interference present in cellular networks, which can significantly improve the availability and quality of network resources and the user experience. Eliminating the need to manually detect and manage sources of interference may, for example, reduce costs and the duration in which a network is negatively impacted.

DETAILED DESCRIPTION

There are numerous sources of external interference that decrease the quality of cellular networks. External sources of interference may include, for example, any radio source, such as baby monitors, security cameras, cordless telephones, wireless headphones, TV stations, and the like. Figure 1 illustrates an example of a directional interference source affecting cells.

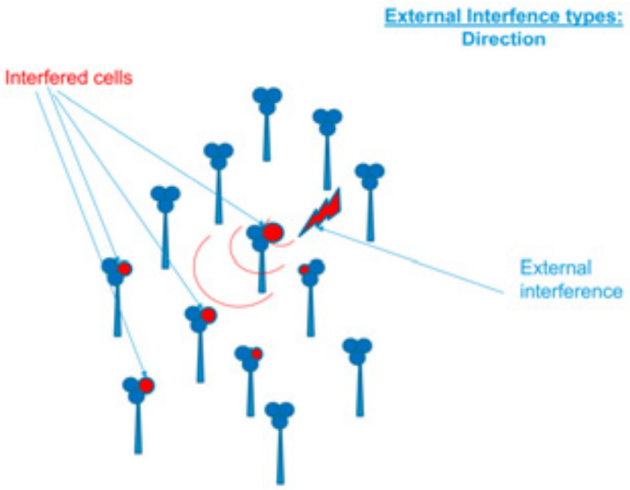


Figure 1

In comparison, Figure 2 illustrates an example of an omnidirectional interference source.

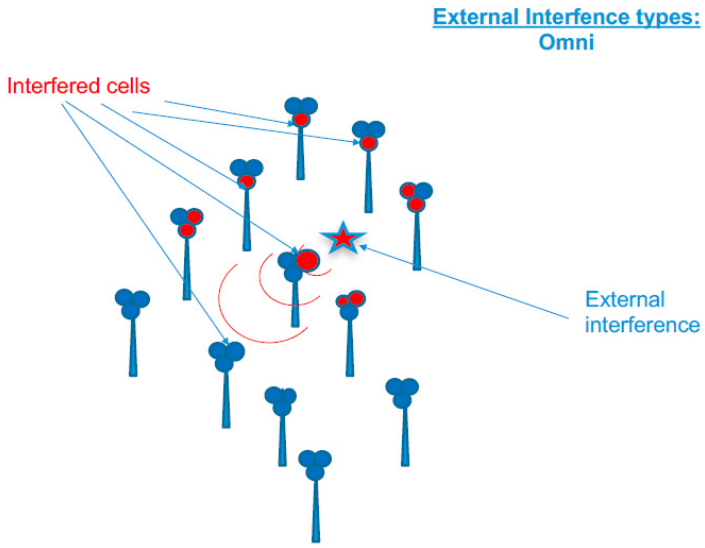


Figure 2

It may be extremely difficult for cellular operators to physically locate sources of interference. Furthermore, even when a source of interference is located, the process of eliminating the interference can be time-consuming. Some sources of external interference can impact dozens of cells.

The embodiments presented herein provide an automatic process for locating and managing external interference sources. The data sources of collected information include interference measurements, such as the interference power distribution in a frequency domain, in a time domain with a direction (azimuth) to the interferer, and according to the distribution of users.

First, the source of interference may be observed graphically. Figure 3 illustrates a graph of power over frequency when there is no external interference.

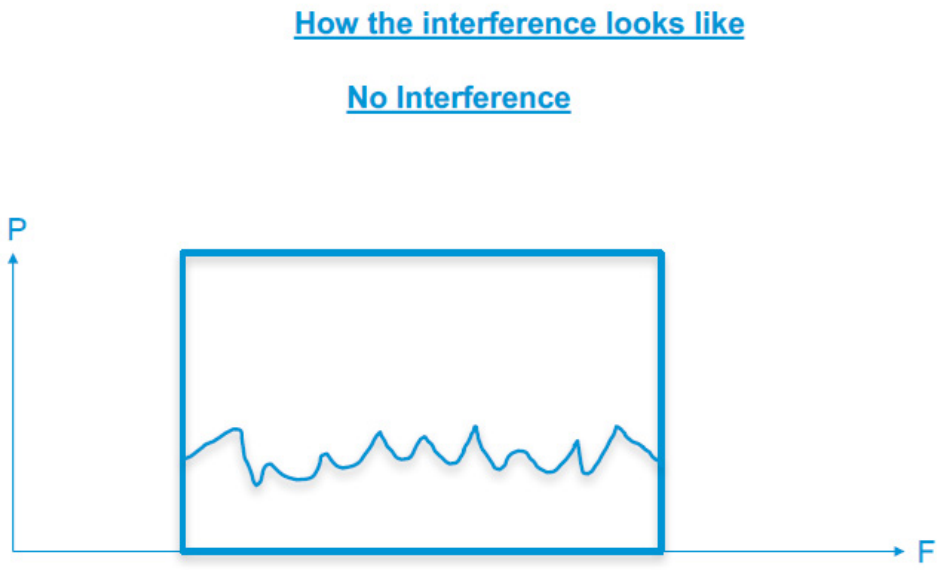


Figure 3

Figure 4 illustrates a graph of power over frequency when there is a narrowband external interference source.

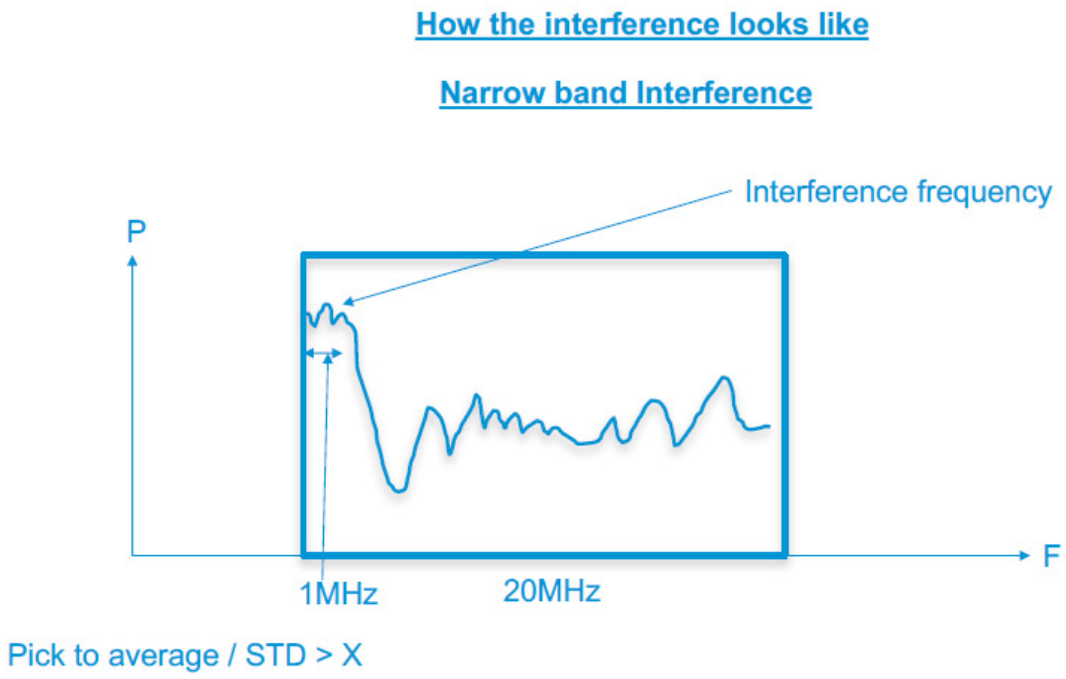
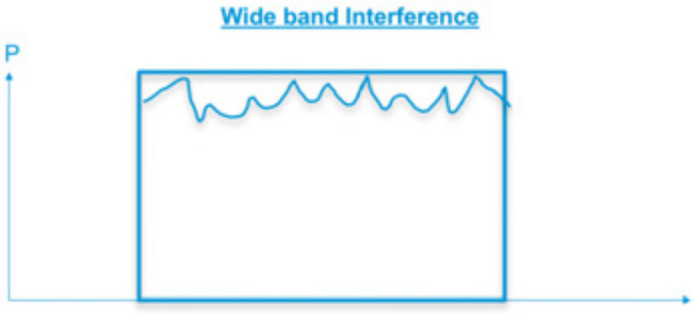


Figure 4

Figure 5 illustrates a graph of power over frequency when there is a wideband external interference source, which can be determined by observing a number of distributed users per received radio strength indication (RSSI).



normal distribution example:

Users	RSSI (dbm)
10	-90
30	-85
50	-80
70	-75

Interference distribution example

Users	RSSI (dbm)
10	-70
30	-60

Figure 5

Areas may be classified according to groups of interfered cells (i.e., cells that are correlated to interference patterns by time and frequency), and sources of interference can be clustered based on directional (azimuth) intersections, and ranked according to the degree to which the area is affected, as measured by the key performance indicators (KPIs) of cells in the area. KPIs may include metrics such as retainability, accessibility, throughput, and the like.

Figure 6 illustrates an example of a directional intersection of multiple cells.

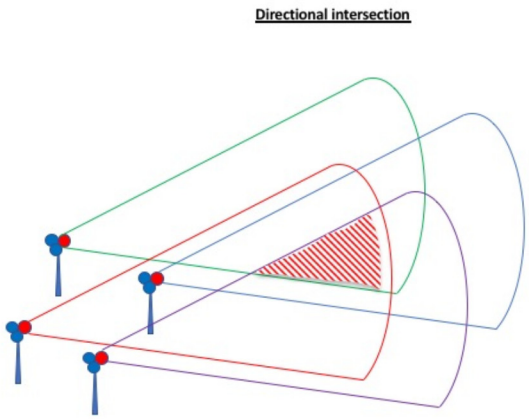


Figure 6

Figure 7 illustrates an example of a source of interference presented on a map as part of the management and monitoring of the interference.

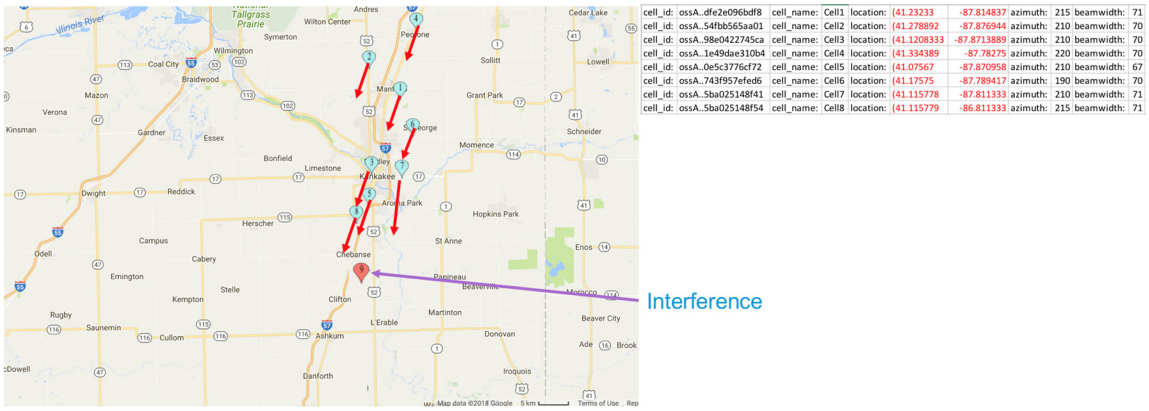


Figure 7

Figure 8 illustrates a PRB histogram over RSSI, "PMRADIORECINTERFERENCEPWRPRB," containing data from ten cells. While external interference can impact cells, all affected cells interfered by the same frequency can be observed.

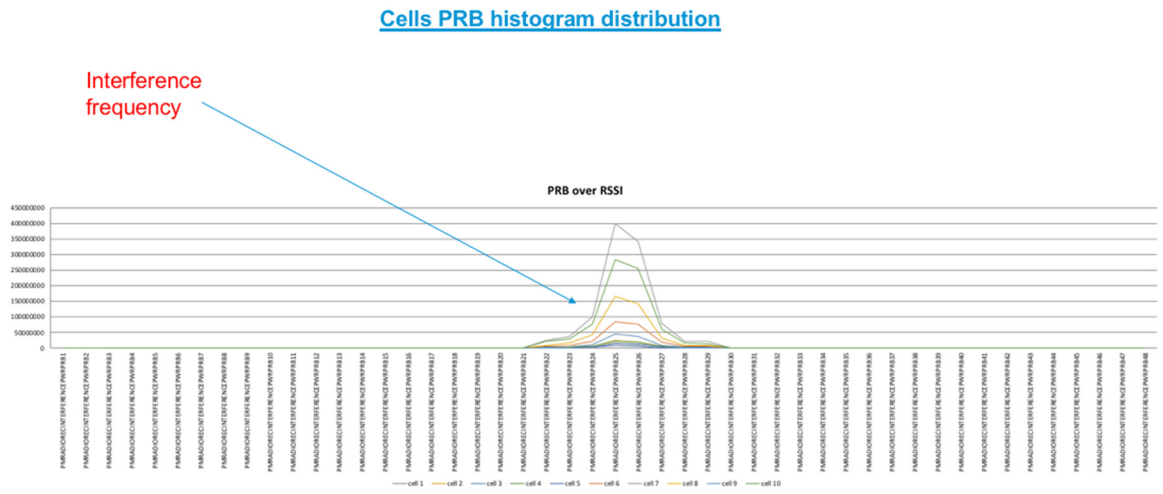


Figure 8

Figure 9 illustrates an example of a PRB over RSSI in which no external interference is occurring. It may be observed that all related cells have the same power over frequency distribution.

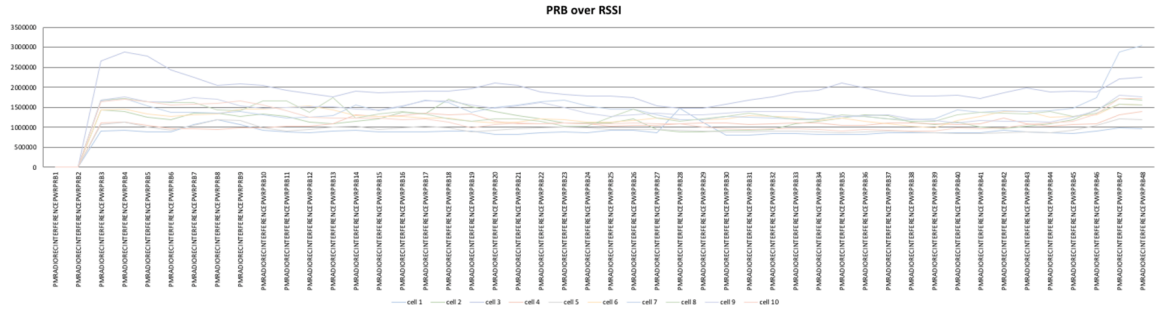


Figure 9

Figure 10 depicts a number of interfered cells distributed by time.

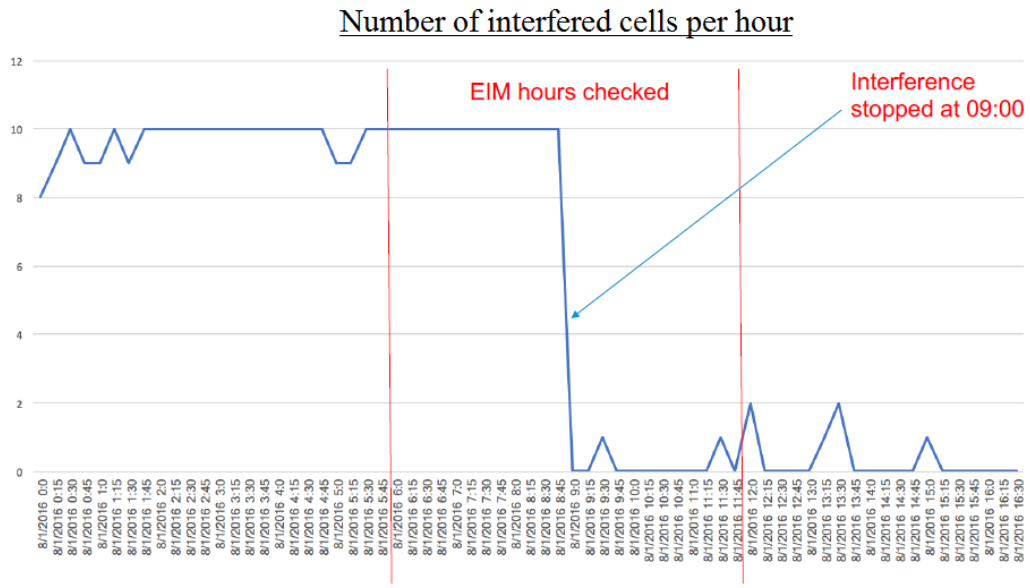


Figure 10

Thus, embodiments presented herein detect external sources of interference by comparing KPIs of affected cells. When an external interference source is located, traffic may be offloaded from affected cells while the interference persists.

Narrowband interference sources may be located by filtering for very strong interferences that affect multiple cells for some time. KPIs for each cell may be measured in order to determine whether a given cell is experiencing interference, and an interfered cell may be analyzed by comparing the interference behavior in two dimensions, time and frequency, with other interferences measured on other cells. After collecting all the interference patterns, a weighted intersection between all involved cells may be calculated to determine the coordinates of the external interference source. Figure 11, below, includes a table of attributes that are useful for determining the location of an external interference source.

App attributes

Attribute	Description	default
cells_radius	Cells Radius to calculate polygon	50
hours_correlation_threshold	How correlate should hours be with interference between cells in order to decide that both cells connected to the same external interference	0.9
nterference_pattern_correlation_threshold	How correlate should the interference patterns be in order to decide that both cells connected to the same external interference	0.9
add_to_beam_width_if_same_location	If cells in the same location need to increase beamwidth in order to get reasonable overlap outside of the cell	60
radius_if_same_location	If cells in the same location need to reduce radius in order to get reasonable overlap outside of the cell	2
pms_resolution	Time resolution of the pms	15
peak_to_avg_as_interference	Peak to average to consider pattern as interference	4
minimum_interference_times	Minimum interference time samples to consider as interference	8
minimum_cells_in_interference_to_show	Minimum cells with interference that interference has in order to analyze it	20

Figure 11

Figures 12-15 illustrate an example of locating and managing an external interference source in accordance with the embodiments presented herein. Figure 12 illustrates a system that raises alerts when identifying external interferences

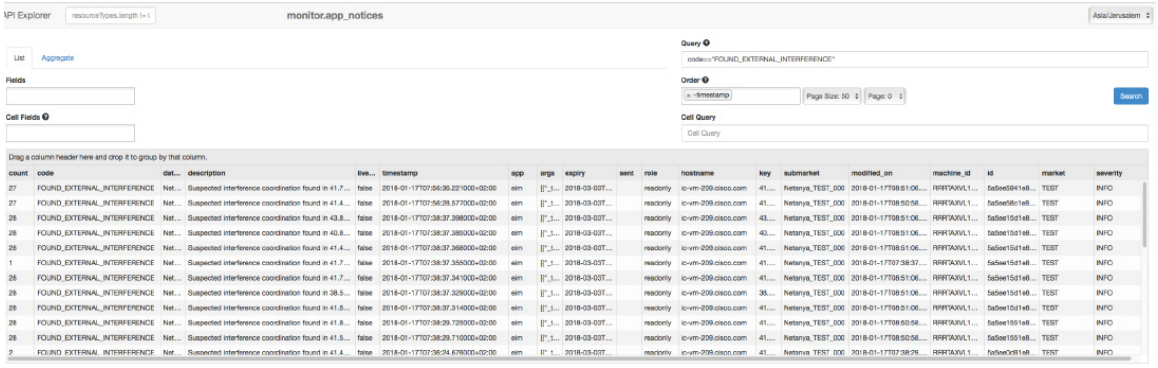


Figure 12

Figure 13 illustrates an example of a detailed interference alert on an estimated location with the interfered cells by time.

APP Notice description

Suspected interference coordination found in 40.868825167,-88.2258477742,
affecting 11 cells,
on hours: 01/08/16 06:00,01/08/16 06:15,01/08/16 06:30,01/08/16 06:45,01/08/16 07:00,01/08/16 07:15,01/08/16 07:30,01/08/16 07:45,01/08/16 08:00,01/08/16 08:15,01/08/16 08:30,01/08/16 08:45,
cell_ids: [
{'strongest_interference': -88.43333710491699, 'cell_id': 'son_cell_id_1'},
{'strongest_interference': -90.29523676625338, 'cell_id': 'son_cell_id_2'},
{'strongest_interference': -93.48352907282019, 'cell_id': 'son_cell_id_3'},
{'strongest_interference': -94.1453873360881, 'cell_id': 'son_cell_id_4'},
{'strongest_interference': -94.57151438074006, 'cell_id': 'son_cell_id_5'},
{'strongest_interference': -95.72206704976938, 'cell_id': 'son_cell_id_6'},
{'strongest_interference': -98.26521518624818, 'cell_id': 'son_cell_id_7'},
{'strongest_interference': -98.97989793898222, 'cell_id': 'son_cell_id_8'},
{'strongest_interference': -99.34201966552666, 'cell_id': 'son_cell_id_9'},
{'strongest_interference': -100.15126430346128, 'cell_id': 'son_cell_id_10'}]

Figure 13

Figure 14 depicts an example of EIM log output in which an external interference source was found that was affecting two cells by the same time and frequency patterns.

log output example

```
eim is running...
getting cells
getting pms
Mapping interferences
found interference with 2 cells: ['son_cell_id_1', 'son_cell_id_2']
Found: 37 unique interferencesCalculating interferences locationsinterference hours:(0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0)
interference pattern:(-119, -119, -119.02897128392966, -119.02897128392966, -119.02897128392966, -119.02897128392966, -119.02897128392966, -119.02897128392966, -
119.02897128392966, -118.8359197319758, -118.8359197319758, -118.8359197319758, -118.8359197319758, -118.65108567503567, -107.28123911265199, -108.35386685883877, -
118.65108567503567, -118.65108567503567, -118.8359197319758, -118.8359197319758, -118.8359197319758, -118.8359197319758, -118.8359197319758, -118.8359197319758, -
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118.8359197319758, -118.8359197319758, -118.65108567503567, -118.65108567503567, -118.65108567503567, -118.65108567503567, -118.8359197319758, -118.8359197319758, -
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119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119, -119)
cell: son_cell_id_1 info: lat: -88.269968, lon: 41.461416, azimuth: 270, beamwidth: 57
cell: son_cell_id_2 info: lat: -88.269968, lon: 41.461416, azimuth: 30, beamwidth: 57
Estimated interference coordinated: POINT (-88.2699680000000058 41.4614159999999998)
eim is Done.
```

Figure 14

External interference sources can be managed when the interference occurs by cell shaping or traffic steering in the interfered cells in order to offload traffic from interfered cells (e.g., by locking a cell, changing thresholds, adjusting a tilt, changing a CIO, changing a CPICH, reducing power consumption, performing bandwidth adaptation, and the like) to less-interfered cells, such as cells in a different band frequency. By rerouting traffic from interfered cells to less-interfered cells, the impact on the network quality can be mitigated

and the subscriber experience improved. When the interference is stopped, the self-organizing network (SON) may rollback changes to their original values. Figure 15 illustrates an example of automatic offloading of traffic from interfered cells to less-interfered cells.

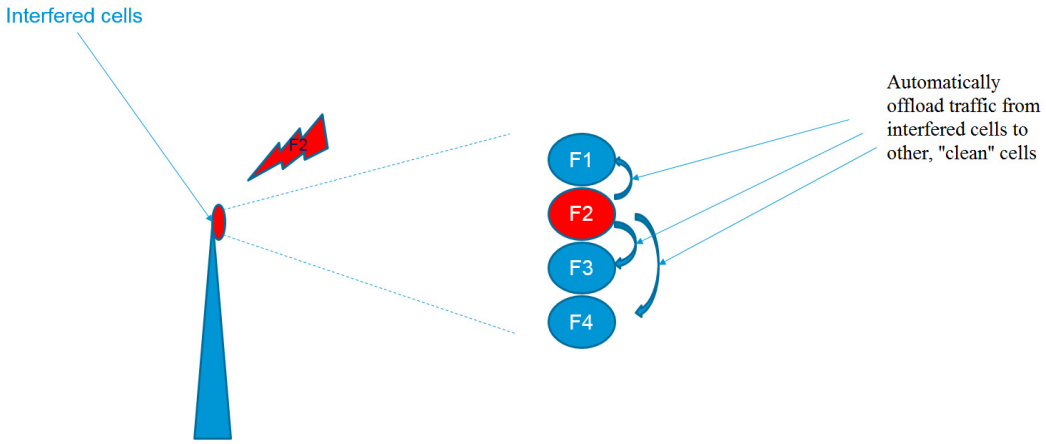

Figure 15