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Optimizing Power Consumption for Mobile User Equipment

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OPTIMIZING POWER CONSUMPTION FOR MOBILE USER EQUIPMENT

Abstract

A mobile user equipment selectively enables access to cells based on its mobility state and velocity, as well as the size of the cells. Power consumption and other resources consumed during handoff of mobile user equipment are optimized by determining whether to enable connection to cells based on how long the mobile user equipment is expected to spend in the cells. Geo-fences are used to mark the boundaries of the cells and the mobile user equipment accesses geo-fence information to determine boundaries of the cells. The time the mobile user equipment is likely to spend in the cell is estimated using the velocity of the mobile user equipment and an estimated distance along a path of the mobile user equipment to a boundary of the cell. Access to the cell is disabled if the time is lower than a threshold that is determined based on resource consumption for connecting to the cell.

Background

Wireless communication systems include a network of cells (also referred to as base stations) that provide wireless connectivity to user equipment within the network. Mobile user equipment hands over between different cells as the mobile user equipment moves through the network. For example, the user equipment monitors received signal strengths from neighboring cells and hands off from a source cell to a destination cell based on the relative received signal strengths from the source and destination cells. Handing off between cells consumes overhead such as the power required to attempt a connection to a destination cell. This overhead is generally worthwhile to maintain a high-quality connection to the network as the user equipment moves from cell to cell. Power optimization is performed based on geo-fence coordinates and sell loads in some cases, *e.g.*, as disclosed in U.S. Patent Publication No. 20190319868, entitled

"Link performance prediction technologies." Power optimization techniques for millimeter wave cells are also disclosed in U.S. Patent Publication No. 20180288674, entitled "Millimeter wave access point states in a cluster set." Monitoring of neighbor cells for cell reselection is disclosed in U.S Patent Publication No. 20130225169, entitled "Method in a device and in a wireless device."

However, if the size of the cell is small or the velocity of the mobile user equipment is large, the user equipment spends a relatively small amount of time in the cell, which may not be sufficient to justify the overhead of attempting to connect to the cell. For example, the low range of millimeter wave communication results in a network that includes a large number of cells of relatively small size. Thus, a relatively fast-moving user equipment may not spend enough time in some cells to justify the overhead. For example, attempting to connect to all the millimeter wave cells along the path of the mobile user equipment represents a significant drain on the energy resources of the user equipment.

Description

Power consumption and other resources consumed during handoff of mobile user equipment is optimized by selectively enabling connection to cells based on how long the mobile user equipment is expected to spend in the cells. The availability of a cell as a destination for handover of a mobile user equipment is determined based on a mobility state, a speed, or a direction of motion of the user equipment.

In order to determine whether a cell is available or unavailable as a destination for the user equipment, the area of the cell is defined using a geo-fence. A geofence is a virtual perimeter for a real-world geographic area. The geo-fence can be dynamically generated - as in a radius around a point location - or a geo-fence can be a predefined set of boundaries such as school zones or neighborhood boundaries. Geo-fences are used to mark cell coverage areas in a wireless communication system.

FIG. 1 illustrates the geo-fence boundaries of cells (indicated by hexagons) as well as a user equipment.

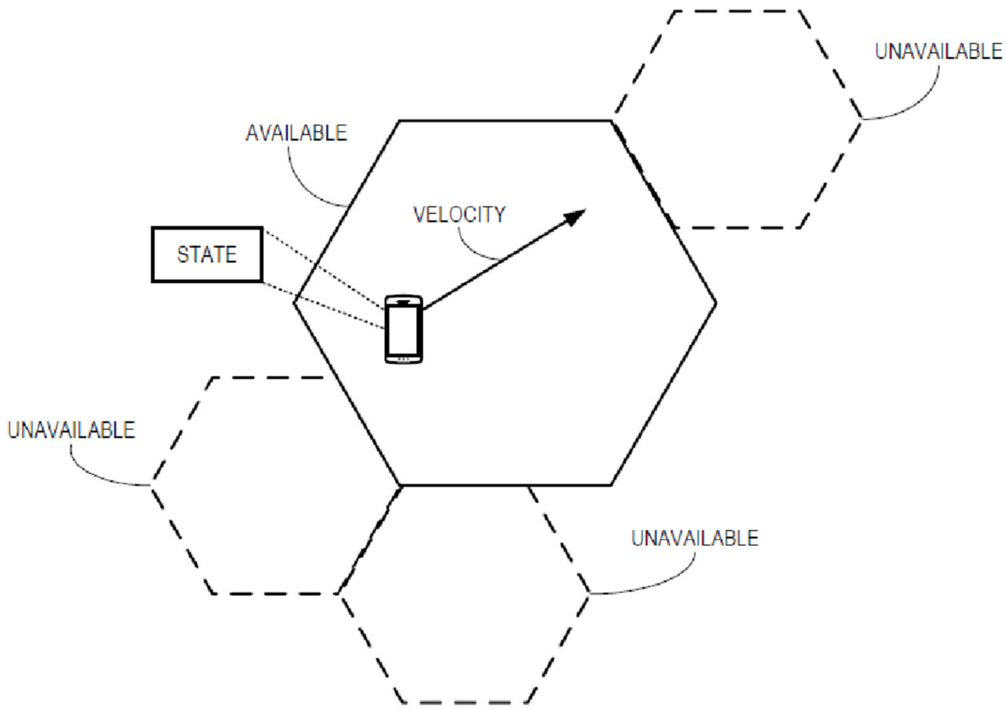

FIG. 1

The time spent by the user equipment within each cell is determined based on the boundaries of the cells (as determined by the marked geo-fence) and the user equipment's mobility state, speed, and direction, e.g., the velocity of the user equipment. A cell is considered available if the amount of time spent by the user equipment within the cell is sufficient to justify the overhead required to attempt to connect to the cell, *e.g.*, if the power consumption for the connection attempt is less than a threshold determined based on the time spent in the cell. Otherwise, the cell is considered unavailable for a handover.

In some cases, relatively low range millimeter wave cells overlap with or are encompassed by the radiofrequency cell that has a larger range. If none of millimeter wave cells within a radiofrequency cell that currently includes a mobile user equipment will ever be useful for connection establishment, *e.g.*, if none of the millimeter wave cells are available, then the user equipment shuts down its millimeter wave transceiver (or radio) a duration of a time that the user equipment is predicted to be in the radiofrequency cell. Consequently, the user equipment does not perform scans or other excess signaling to establish a bearer in any millimeter wave cells, thus saving power consumption.

A mobile user equipment selectively attempts to access cells based on its mobility state and velocity, as well as the size of the cells. For example, if the user equipment is in a first cell that operates according to Long Term Evolution (LTE) standards and overlaps or encompasses a set of millimeter wave cells, the user equipment can fetch geo-fence coordinates for the millimeter wave cells. The geo-fence coordinates could be pre-fetched offline for a larger geographical area and stored in the user equipment for subsequent use.

The user equipment determines whether it is in motion, e.g., using sensors or location services to estimate the speed and direction of motion of the user equipment. The user equipment estimates the time it will spend in each millimeter wave cell. For example, the user equipment can use the direction of motion to determine a distance along this direction to the nearest cell boundary (defined by the geo-fence) along the current path of the user equipment. The user equipment estimates the time to reach the nearest cell boundary based on the speed of the user equipment. If the estimated time is less than pre-defined threshold T1, then the millimeter wave cell is considered virtually unavailable to the user equipment. The unavailable millimeter wave cells are stored in a temporarily blocked list. This process is repeated for all the millimeter wave cells within (or overlapping with) the LTE cell that currently includes the user equipment.

The user equipment decides whether to enable or disable millimeter wave communication (*e.g.*, turn on or turn off the millimeter wave transceiver or radio) based on the available and unavailable millimeter wave cells. The user equipment estimates a next available millimeter wave cell after negating the virtually unavailable millimeter wave cells. The user equipment then estimates the time required to reach the next available millimeter wave cell, *e.g.*, based on the geo-fencing information and the velocity of the user equipment. If the time estimated to reach the next available millimeter wave cell is longer than a threshold time T2, the user equipment disables communication with the millimeter wave cells for the estimated time to reach the next available millimeter wave cell. The threshold time T2 is based on the overhead required to attempt to connect to the millimeter wave cells. If the estimated time to reach the next available millimeter wave cell is less than the threshold T2, and there are one or more virtually unavailable millimeter wave cells on the predicted root of the user equipment, then the user equipment is configured to avoid acquiring these cells. One method is to configure the user equipment not to send measured signal information for these virtually unavailable millimeter wave cells to the network.

Since estimates of the speed or the direction of the user equipment could be error prone, the user equipment is permitted to attempt to access millimeter wave cells that were previously blocked if the initial prediction of the time spent in the millimeter wave cell is incorrect. For example, if a temporarily blocked millimeter wave cell is detected, the millimeter wave cell is moved out of the temporarily blocked list if the signal detected by the user equipment is still good for more than the estimated time that the user equipment was expected to be within the geo-fence of this cell. The user equipment can therefore attempt acquisition of the previously blocked millimeter wave cell.