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PREDICTING 5G USAGE AND RESOURCE CONTENTION THROUGH REAL-TIME MASS TRANSIT AND TRAFFIC MAPPING

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ABSTRACT

Internet of Things (IoT) and sensor fusion techniques may be used to collect data about the current positions and anticipated movements of wireless subscribers, thus enabling fifth-generation (5G) networks to proactively avoid overloads by modifying their capacities and coverage patterns. Data may be collected, for example, from mass transit systems, smart highway systems, smart buildings, security cameras, 5G networks themselves, and other sources, and machine learning techniques may be applied to generate maps of anticipated load patterns. As a result, the 5G networks may then be adjusted to address overloads in various manners, such as by adjusting the service bandwidth, by realigning antennas and multiple in, multiple out (MIMO) systems, by dispatching mobile cells, *etc*.

DETAILED DESCRIPTION

Although 5G cellular networks can provide a better quality of service, the demand for data, mobile edge computing, and improved network performance requires that 5G network resources be intelligently allocated. For example, 5G networks may experience focused-load situations where local bandwidth demands exceed a network's local carrying capacity. The potential for localized overloads is especially a concern in small cellular deployments, such as microcells, where a given cell may be designed to serve a much smaller number of active subscribers. Unlike traditional cells, smaller cells cannot smooth a load over a large number of subscribers. By enabling 5G networks to be aware of traffic

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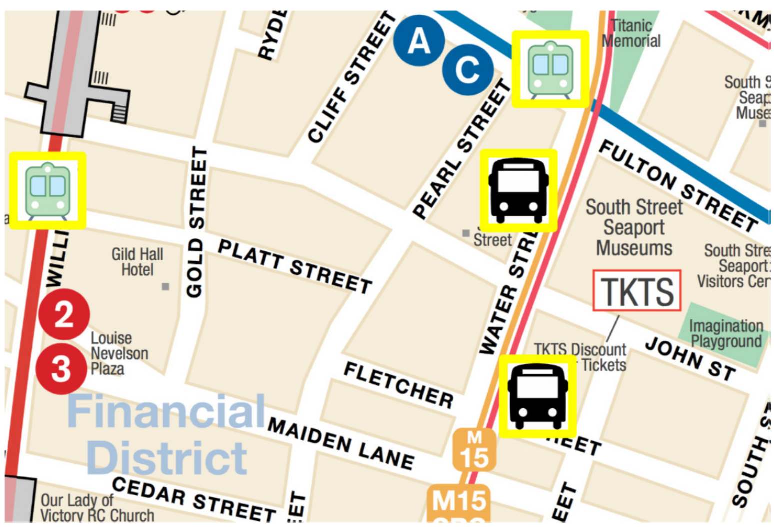
surges and to predict future usage, resources may be allocated more efficiently. In urban areas, surges may be caused when mass transit vehicles (such as trains and buses) filled with multiple mobile users travel through multiple 5G nodes over the course of the vehicles' routes. Similarly, a wave of cars may cause periodic surges whenever it is stopped at intersections or traffic jams. As another example, a fully-loaded commuter train can transport over one thousand subscribers at a time who, at full speed, may only be in range of a given small cell for a minute or two. Such a large volume of fast-moving users may overload networks while in transit, and may furthermore contribute to network overload upon arriving en masse at the train's destination.

The embodiments presented herein integrate data collected about the movement of mass transit vehicles with traffic controllers, video and network analytics, and various IoT sensor modules to locate and predict concentrations of wireless network users. With sufficient data about the locations of current and projected future network loads, steps can be taken to re-balance the local capacities of 5G or other wireless networks.

As cities upgrade towards "smart city" architectures, they may deploy devices that track mass transit systems in real-time. Since trains and buses typically travel along pre-planned routes, maps can be generated to show where each train or bus is located on their respective route at any point in time. Figure 1 depicts a mock-up real-time map of buses and trains (outlined in yellow) overlaid on a New York City mass-transit map.



<u>Figure 1</u>

A real-time map may be generated using direction and speed data from buses and trains. Schedule databases and machine learning techniques can be applied to predict future events such as arrival times. Furthermore, real-time data from a transit system's fare collection devices can be analyzed to estimate the fullness of buses and trains.

In addition to collecting data about vehicles and their passengers by using smart transportation systems, devices such as traffic cameras and sidewalk security cameras can acquire images of the environment to provide additional data regarding the positions and movements of network subscribers. IoT data sources, such as high-rise elevator load factors, door operation logs, and real-time retail sales data, can help estimate the movements of people. 5G and Wi-Fi networks themselves may also report the positions of the subscribers using location-based services.

Data collected from all of these sources can be combined to provide clearer insights into where network loads may be focused due to subscribers in transit. Furthermore, machine learning techniques can analyze the data to extrapolate future occurrences, such as estimating the destinations of subscribers, to determine whether the movements of subscribers are likely to contribute to a future network capacity overload (for example, if there is a sports event, concert, rally, parade, etc.). This information can be overlaid or combined with a provider's wireless access point locations. Figure 2 illustrates some cell tower locations (emphasized by the yellow outline) in the same area that was depicted in Figure 1.

Figure 2

As 5G cells are rolled out, more cell locations with smaller coverage areas may be deployed. In order to avoid situations where large numbers of users entering the same cell location area may cause resource contention issues, embodiments presented herein consider factors such as mass transit schedules, traffic infrastructure, and various smart sensors to better predict and mitigate usage spikes. For example, events where multiple subway trains and city buses are simultaneously located in the same cell can be anticipated, enabling a 5G network to take explicit measures to better prepare for an event before subscribers notice any slowdown.

Traffic control networks may provide one source of data for managing 5G networks. Waves of cars passing through, or stopping in, a 5G coverage area can cause contention for a 5G node. With car models featuring their own cellular connections, and self-driving cars giving their passengers more time to consume media on their bandwidth-hungry mobile devices, it is expected that the data consumption of individuals in cars will only increase. While waves of cars can overload 5G nodes during peak hours (such as rush hour), such occurrences can be predicted and automatically mitigated.

Future usage of 5G network resources can be predicted using machine learning techniques. For example, machine learning models can be fed transit routes, schedules, and traffic controller algorithms. Machine learning algorithms can be trained by observing real-time maps of traffic systems. Furthermore, machine learning algorithms can analyze security camera images and various load indicators from smart buildings in the area. By correlating the collected transportation data with spikes in 5G node usage, machine learning algorithms can be trained to reliably predict spikes in traffic for any day and time. This algorithmic approach can also learn event patterns in order to predict outliers associated with concerts, sporting events, and the like. Once a machine learning technique has predicted where and when a local network load will exceed a local network capacity, steps can be recommended to address the overload and minimize any negative impacts to network subscribers. By providing a system with multiple sensor modes and machine learning techniques to anticipate the location, time, and severity of network overloads, networks can react to high-usage events before network users notice a slowdown.

If traffic is projected to exceed local network capacity, various mechanisms can be used to proactively adapt to the upcoming surge. For example, stationary users in a cell coverage area can be switched to a Wi-Fi only mode, or bandwidth for video streaming could be proactively reduced or intentionally increased to enable user devices to buffer up a reserve before the surge occurs. A wireless access points can also make adjustments to its operation to optimize and relocate bandwidth. If multiple cells or Wi-Fi access points cover an area where a crowd is expected, those cells or access points can reconfigure their antennas (e.g. by adjusting tilt, refocusing their MIMO, etc.) to provide better coverage patterns in higher-usage areas. Given that a system can predict some types of loads up to an hour in advance, mobile cells, such as Cells on Wheels (COWs) or Cells On Light Trucks (COLTs) could be dispatched to locations that correspond to network hot spots, and brought into service to supplement the fixed network nodes on a temporary, just-in-time basis. In the future, Cells on Autonomous Vehicles (COAVs), such as ground robots or drones, can provide fine-granularity network supplementation on timescales smaller than five minutes.

If a system can predict where focused network loads will occur at various times in the future, the system can schedule the various network capacity enhancements described above to follow the location of the loads. For example, during a holiday parade or marathon, the cells along the route may leapfrog their areas of enhanced coverage in order to follow a crowd along the route. By scheduling anticipated cell network configuration changes, mobile resources like COLTs, COWs, and COAVs can be dispatched accordingly.

A significant control infrastructure may be required to manage systems proposed herein. Sensor fusion may be performed to correlate data, with a focus on predicting 5G and Wi-Fi network loads based upon the anticipated movements of network users. Heuristic algorithms that employ machine learning techniques may determine the particular areas in which network capacity is likely to be exceeded, and for how long. Based on the results of the heuristic algorithms, the system may determine optimal network configurations to meet the anticipated focused load. Solutions like bandwidth control on video streams or conversion of a subset of the traffic from 5G to Wi-Fi may alleviate the network's overloading. Additionally, 5G and/or Wi-Fi access points near the anticipated overload can be reconfigured by adjusting their antenna angles or MIMO settings to modify their coverage patterns. Furthermore, the system may dispatch COWs, COLTs, or COAVs to fill any remaining gaps.