September 26, 2018

RELIABLE LTE LINK SWITCHOVER FOR IN-VEHICLE NETWORKING

Robert Barton

Nagendra Kumar Nainar

Jerome Henry

Carlos M. Pignataro

RELIABLE LTE LINK SWITCHOVER FOR IN-VEHICLE NETWORKING

AUTHORS:
Robert Barton
Nagendra Kumar Nainar
Jerome Henry
Carlos M. Pignataro

ABSTRACT

The embodiments presented herein relate to controlling backhaul routing of a mobile router with multiple cellular uplinks. The router has dual-LTE links to different providers that both use cellular management systems. A gateway management module communicates with both providers to gain a full picture of the cellular billing and usage, as well as cellular performance on each provider's network. The gateway management module then becomes a central control point, communicating with the router to control which LTE backhaul link should be used at any given time.

DETAILED DESCRIPTION

Connected vehicles commonly utilize mobile routers that have primary and secondary backhaul radio links. These links are often both LTE links that are connected to two different service providers. In most cases, only one link is active at a given time, with communications being attempted on the primary link first, and the secondary link serving as a backup. This redundancy is necessary, as a vehicle may encounter geographical areas in which one provider has limited coverage, but another provider has satisfactory coverage. In conventional approaches, a router's decision as to which LTE interface to use is straightforward, with the primary link on always, and the secondary link turned on if the primary link’s signal is lost.

This scheme is inefficient, as the cost of service from both providers needs to be paid, resulting in a suboptimal cost model. For example, large data usage may result in overage fees on the primary provider account, and the backup provider account will still require payment even if the service is largely unused. Additionally, this model is reactive rather than proactive, resulting in location with suboptimal efficiency (poor connection before temporal loss, where the system reacts after the problem has occurred).

As most fleet management systems start integrating with more advanced management tools, there is a need for a proactive solution that will optimize the LTE billing and backhaul connectivity through intelligent LTE backhaul switchover.

The embodiments presented herein present a solution to intelligently solve the link choice problem. When the dual-LTE mobile router is placed on a vehicle, the two LTE links are typically associated with different cellular carriers. Increasingly, mobile carriers are using an LTE SIM management system. A single control center may have no visibility into the LTE activity of another control center. However, with cloud-based central management systems for IoT-enabled devices, a central control point for the two backhaul options can be used.

In some embodiments, a gateway management system connects to multiple LTE IoT data management systems and collects data in (near) real time. The gateway management system now has a complete picture of the LTE performance of both carriers, and is able to compare the usage of both LTE connections with the usage and billing contracts. Figure 1 depicts an example of a gateway management system connected to two LTE IoT data management systems.

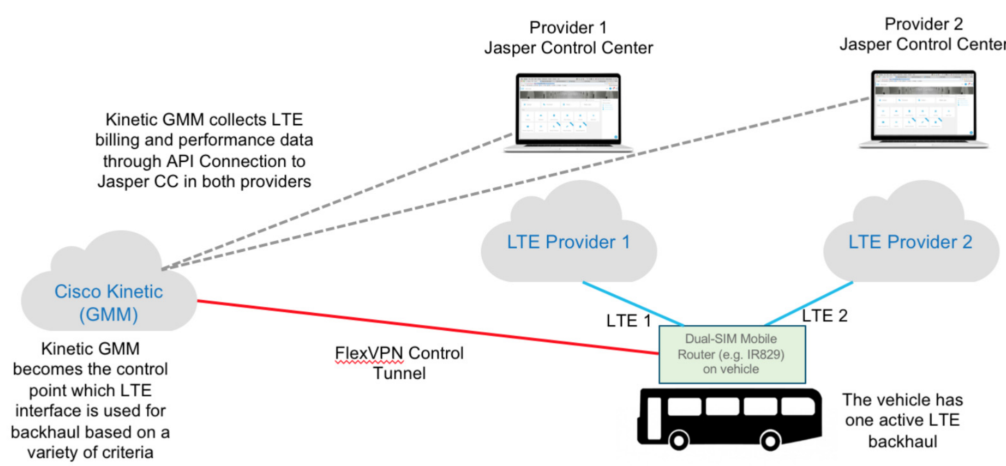

Figure 1

As the cellular data consumption on a primary link reaches a predetermined threshold, the gateway management system may instruct the mobile router to switch to the secondary link associated with the other LTE provider. The predetermined threshold can be determined in several ways, such as by using a simple scalar (e.g. a cost measurement), or a comparison scale (comparing usage of the two links on the current billing cycle), that can also be expressed in terms of time (duration on the primary link vs. the secondary link), data (e.g., in kilobytes), monetary value (e.g., the primary link's current bill vs the secondary link's current bill) and the like. In this way, billing may be optimized between the two carriers.

The gateway management system may record the mobile router's GPS location. The gateway management system may then compare the router's GPS location to a coverage map of the service provider (e.g., via one or more APIs). When a vehicle reaches an area of poor coverage for the primary provider, the gateway management system can dynamically switch the router link to the secondary provider. This switch decision can be combined with the threshold-based switchover, and may also take into account hysteresis (by switching when the secondary signal is X percent (%) of Y dBm higher than the primary signal). In this way, the gateway management system may serve as a control plane for the LTE backhaul selection based on analyzing the data received from the two carriers.

The gateway management system may record a history of connection losses. In a connected fleet, it is expected that in multiple cases vehicles will patrol the same locations. The gateway management system can associate geo-coordinates to particular LTE link losses. By comparing the vehicle's current location to the recorded location of link loss, the gateway management system can predict that a vehicle is likely to reach an area of limited connectivity. The gateway management system can then instruct the router to switch to the backup link before the vehicle reaches an affected area. For example, if a vehicle's current location is within a predetermined geographical distance to an affected location, a switchover may occur. Alternatively, the computation can be more elaborate, with the gateway management system may record a vehicle's geolocation over time to determine whether the vehicle is traveling toward an affected area, and perform a switchover only when the vehicle is actually heading in the direction of an affected area. Figure 2 depicts an example of a switchover based on a vehicle's geolocation

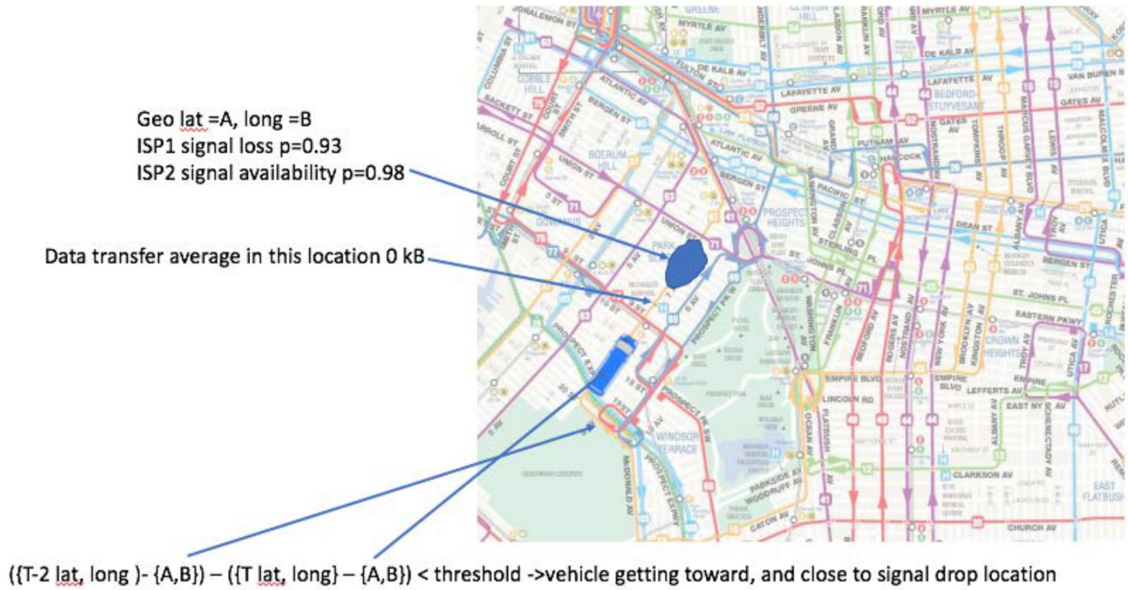

Figure 2

The gateway management system may be connected to a machine learning system, enabling the gateway management system to learn from historical connection data. For example, the gateway management system may learn the date and time of connection losses, and correlate losses with events (e.g. weather systems that may be affecting the edge of the connection area). The gateway management system may correlate location with data consumption, thus anticipating locations where link data consumption may change. Similarly, the gateway management system may correlate location with link performance. In these cases, the gateway management system can anticipate the location where a switchover to the secondary provider may be necessary, enabling the system to perform a switchover in advance. By anticipating the connection needs, Kinetic can also cause the connection switch at points where the need for data exchange is learned to be low. Thus, a switchover operation can be performed before actual signal loss by performing the switchover at a point of low data exchange (and/or coupling the switchover with a mechanism that uses a protocol such as QUIC or MP-TCP). The switchover mechanism can be further granulized to perform backend analytics, to identify the optimal choice of provider for different critical applications, and to suggest the use of both interfaces for particular applications.