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DISTRIBUTED LOCATION PROCESSING USING REVERSE TRACKING AND AN INTERNET OF THINGS PLATFORM

Jeff Apcar

Vinay Saini

Ankush Arora

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AUTHORS:

Jeff Apcar
Vinay Saini
Ankush Arora

ABSTRACT

The concept of location tracking is of great relevance in various enterprise and industrial environments. The techniques presented herein propose location tracking techniques that are independent from centralized servers and that use scalable technology and architectures to provide resiliency, faster location updates, reduced cost, and increases reliability.

DETAILED DESCRIPTION

Location tracking is an important capability requirement in a multitude of industry verticals, such as Retail, Industrial, Campus, Warehouse, Mining, etc. A variety of use-cases are predicated on tracking the location of an asset or individual. There are several non-GPS geo-location systems available today that are based on different wireless techniques (BLE, LORA, WiFi etc.) accompanied by complex algorithms such as Time Differential of Arrival (TDoA) or Angle of Arrival (AoA). Such systems provide a varying degree of accuracy and often the price and complexity of the solution increases in proportion to improved accuracy.

While wireless geo-location systems provide reasonable accuracy in an open area, such as a warehouse, they are faced with major challenges when deployed in areas such as a narrow tunnel, underground mines, and other space constrained areas where triangulation cannot be performed with sufficient accuracy and/or signals cannot penetrate far enough. If connectivity to a central location server is lost (e.g., due to cable cuts or power loss), then the location system is rendered useless. As such, there is a need for a mechanism to provide a basic location function which is independent of standard triangulation/TDoA methods and that can operate in a distributed manner in harsh environments such as tunnels and underground mines. There is also a need to have a location system that can work autonomously when communication to other parts of the system are disrupted.

Proposed herein is a very simple and unique approach for location tracking without the need of triangulation/TDoA/AoA methods by transmitting local position beacons that are received and processed onboard by the target asset (usually something large, such as an underground articulated truck). The basic concepts are founded on the asset being tracked radiating back received location beacon information and piggybacking that information with additional data that identifies the asset plus optional telemetry (e.g., temp, humidity, speed, etc.) to specialized nodes working in tandem. The techniques are designed to be deployed in an environment where there is no GPS availability and very limited RF reach for wireless signals, such as an underground mine or similar environment. The techniques presented herein may be divided into two parts, namely: (1) location infrastructure, and (2) distributed location calculation of location data. The techniques presented herein propose the use of small and inexpensive low energy wireless radio nodes for example, LoRA or BLE, which will be placed at various locations within the target areas (tunnels).The separation distance between these radio nodes will vary based on the accuracy required. Some of these nodes can be small battery-powered devices, whilst others may need a larger battery or constant power feed.

The techniques presented herein consist of two types of beacons, namely BeaconLocation, and BeaconAsset.

- **BeaconLocation -** A tag that contains location information to identify the position of a radio node in the tunnel or area.
- **BeaconAsset -** Information frame used by a moving asset to identify itself and its location, which it has learned from a **BeaconLocation**.

The nodes are categorized into four types (three stationary nodes, one mobile node). These nodes include:

- **Beaconer Node (Stationary)**
  - The Beaconer Node sends small radio messages called a **BeaconLocation** over a low power radio technology such as LoRa or BLE. Beaconers can be installed at every few meters within a space (e.g., tunnel) and are

powered on based on a specific signal from the monitor node in order to conserve energy. These devices will send a location beacon containing the node's position in the space at a configured interval (e.g., every 1 second whilst in the ON mode).

- **Transporter Node (Stationary)**
  - The Transporter node has connectivity with back-end server (backhauled via WiFi or wired).This device requires more power and processing abilities. There are much fewer Transporter Nodes than other node types. Transporters can also send BeaconLocation tags, if required.

- **Reflector Node (Mobile)**
  - The Reflector is the node that resides on the asset (e.g., moving vehicle within the mine) which receives location info from the **BeaconLocation** tag, adds its vehicle ID and reflects a **BeaconAsset** information frame back to the stationary nodes capable of processing the information (Monitor and Transporter nodes). The Reflector Node will use a low energy transport such as BLE or LoRa. It is quite possible that the Reflector Node will receive **BeaconLocation** tags from multiple nodes (i.e., multiple locations). In this instance, the Reflector Node will choose the **BeaconLocation** message with the strongest RSSI which will be closest to the asset. The Reflector Node could also enhance the **BeaconAsset** information frame by including telemetry such as fuel level, engine temperature, air quality etc., therefore providing valuable insights into the health of the immediate environment.

- **Monitor Node (Stationary)**
  - The Monitors are nodes that can receive and process **BeaconAsset** information frames from Reflector Nodes. This node also has the capability to send **BeaconLocation** tags. Monitor Nodes are positioned at strategic locations, such as the entrance of the tunnels.

- The Monitor Node also assists in power saving for stationary beaconer nodes. As the Beaconer node is highly likely to be a battery-operated device, continuously sending beacons on-air will reduce the battery life. To avoid this, the Beaconer nodes will enter into promiscuous or listen-only mode after a configured time when no message is received from any reflector node. The Monitor Node which is always active and reachable, will send a specific notification to the nearby Beaconer Nodes when it sees a vehicle entering the tunnel. Every node will send a wakeup notification to next node (configurable parameter).

Figure 1 illustrates an example distribution of nodes in accordance with one implementation of the techniques presented herein.

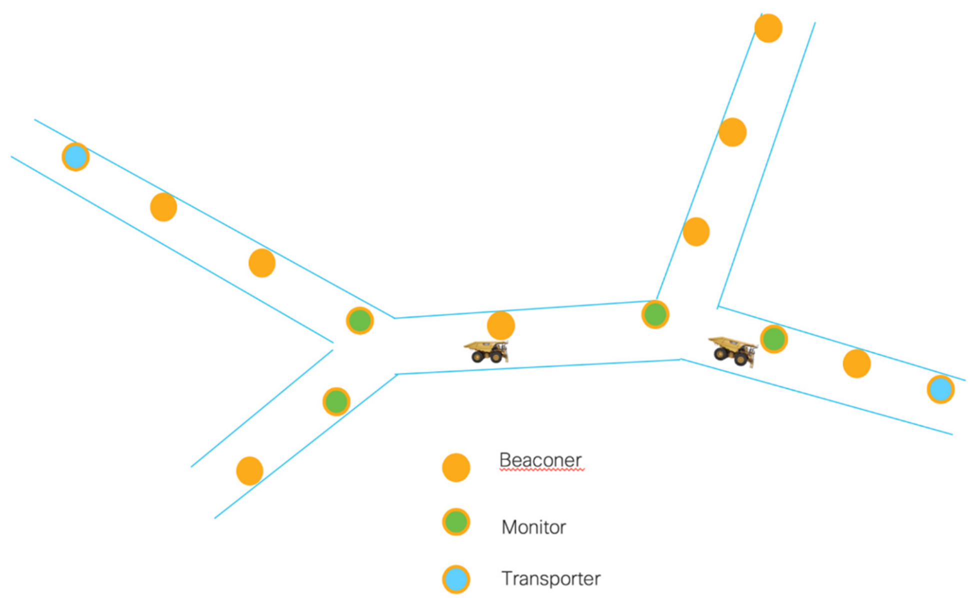

Figure 1

In general, the location determination is based on the **BeaconLocation** tag broadcast by the stationary nodes and the vehicle ID added by the Reflector Node (asset) in the corresponding **BeaconAsset** information frame. The **BeaconLocation** tag is based on identifiers, such as Tunnel Number, Pillar Marker, Relative position. The "Location Function" is the Location Tag plus the asset (e.g., Vehicle) ID. This is shown in Figure 2..

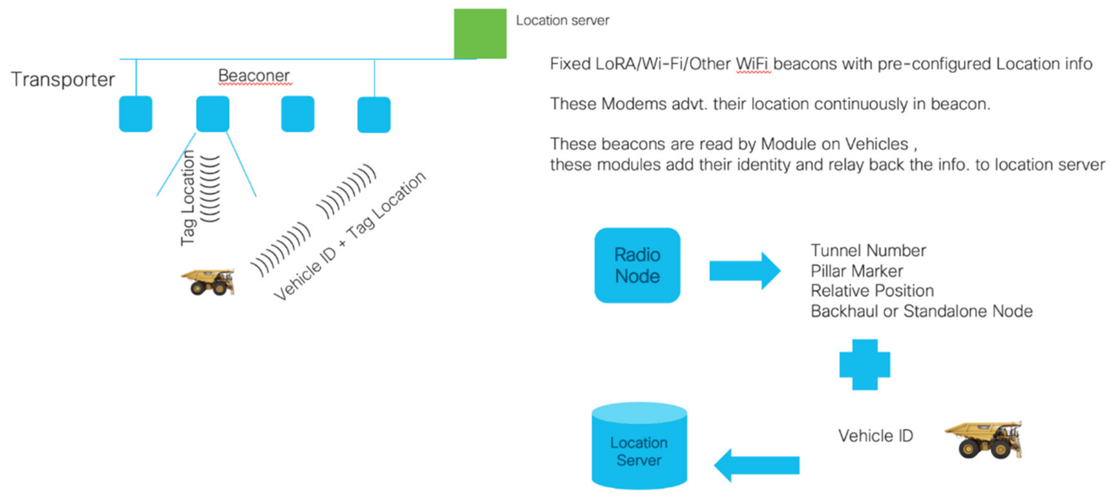

Figure 2

In accordance with the techniques presented herein, each stationary node (Beaconer, Monitor, Transporter) can send a location tag beacon based on a configured periodic interval. In addition, every unique **BeaconLocation** created will be added to the management system and pre-programmed into the stationary nodes with the exact location information (e.g., Tunnel Number, Pillar Marker, etc.). This information makes up the location tag transmitted in the BeaconLocation.

In addition, the asset that needs to be tracked has a Reflector Node attached to it. The Reflector Node appends its vehicle ID (and any other telemetry information) to the location tag received and reflects it back on the air in a **BeaconAsset** information frame. The monitor node scans for **BeaconAsset** information frames from the device/asset in motion. The Reflector Node will then forward the received **BeaconAsset** information frame towards the Transporter Node using a unicast packet over WIFi or other radio technology. As each stationary node is has a limited coverage area, the location of the asset will be processed based on proximity to the closest **BeaconLocation** received with the best RSSI.

When the Transporter Node receives the **BeaconAsset** information frame it will relay it to a Location System over a network backhaul which has prepopulated information about the tunnel maps and position of nodes. The Transporter Node could also perform an edge computing function (e.g., using an IoT platform) before forwarding the **BeaconAsset** information frame to the Location System. For example, it could filter the BeaconAssets without a Vehicle ID, remove duplicates, etc. It could also perform distributed location calculation or generate alerts as explained below. Figure 3 illustrates data added by different nodes.

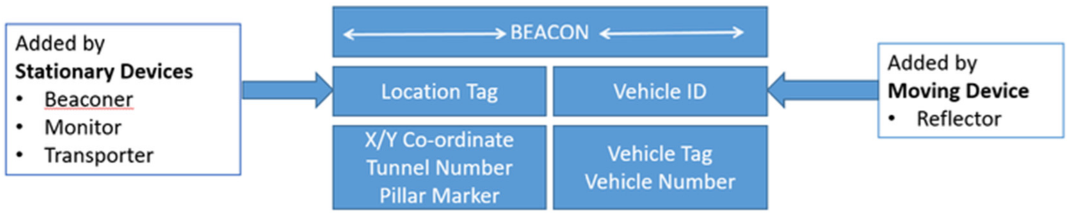

Figure 3

Each Transporter Node will act as a base station for a specific area and nodes group (Beaconer & Monitor). The Transporter Nodes will be provisioned with a local map where other related nodes are placed, providing a local view of the area. An IoT platform edge function running locally will process the location information and track different moving assets (vehicles) within its vicinity. The edge function on the Transporter Node could analyze the possibility of collisions or other problems (truck has been stationary for too long, temp too high, Co2 level too high) and generate local alerts pertaining to the location, such as congestion or collision probability right at the edge and send alerts to local users or central location via available means. This data will be further sent to the central location system/server to provide a comprehensive analysis of tunnel performance.

As shown in Figure 4, the edge software in the IoT platform will allow access to local map and location information for that area even if there is a loss of connectivity upstream.

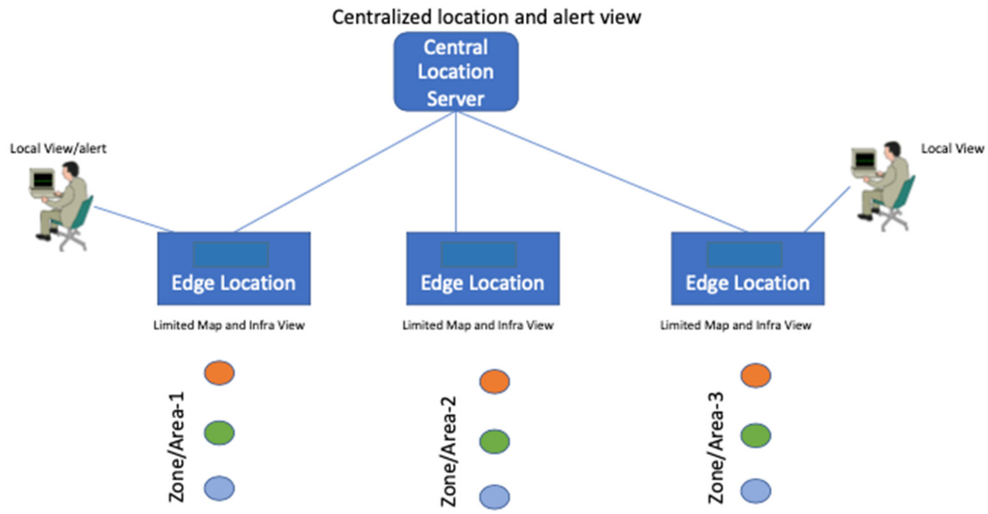

Figure 4

An enhancement to the techniques presented herein could place intelligence within the Reflector Node that could be equipped with a hardware (e.g., accelerometer and/or gyroscope) to monitor speed and angular momentum of the asset. The Reflector node could do location calculation of the speed and direction of the asset based on the last BeaconLocation it received. In this way, it may be possible to reduce the amount of Beaconer Nodes required or increase the distance between Beaconer Nodes.

The techniques presented herein can be deployed using an IoT platform and edge processing in conjunction with WiFi/LoRA/BLE based location systems. Distributed location calculations can be performed on edge nodes. This creates a unique solution that will be able to function even if there is a loss of connectivity with central servers or some part of infrastructure is down, where such situations are common in industrial and mining environments.