Interoperable Connected Intersection Monitoring at Scale

Panasonic

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Connected Intersection technology is a great benefit to roadway safety by reducing congestion, crash probability, incident response time from emergency providers, and more. There are multiple methods and technologies to deploy connected intersections, making interoperability a key consideration in designing a scalable system management solution. This concept extends further into the services that monitor the status of deployed devices, and the data received from them.

For safety applications, this data must be verified, trusted, and reliable. If intersections are configured incorrectly such that the operation of connected intersection infrastructure is compromised, that will cause traffic and safety issues on the road. This situation can occur if the data does not accurately match roadway environments.

This is where the Connected Intersection Message Monitoring System (CIMMS), originally developed by the Connected Vehicle Pooled Fund Study, comes in. The objective of CIMMS is to continuously monitor the operations of V2X connected intersection infrastructure over long-term operation for discrepancies between data and real-world conditions.

Here we explain how the CIRRUS Team at Panasonic leveraged and expanded CIMMS to remotely monitor connected intersections at scale while also making it extensible for V2X and non-V2X deployments.

One of the key aspects of the Connected Intersection Message Monitoring System is to show what data the system is reporting and to attempt to identify desynchronization between data and roadway activity.

Key Use Cases

To understand the use cases for CIMMS, it is necessary to know how the CIRRUS team defined the components of an intersection (see Figure 1).

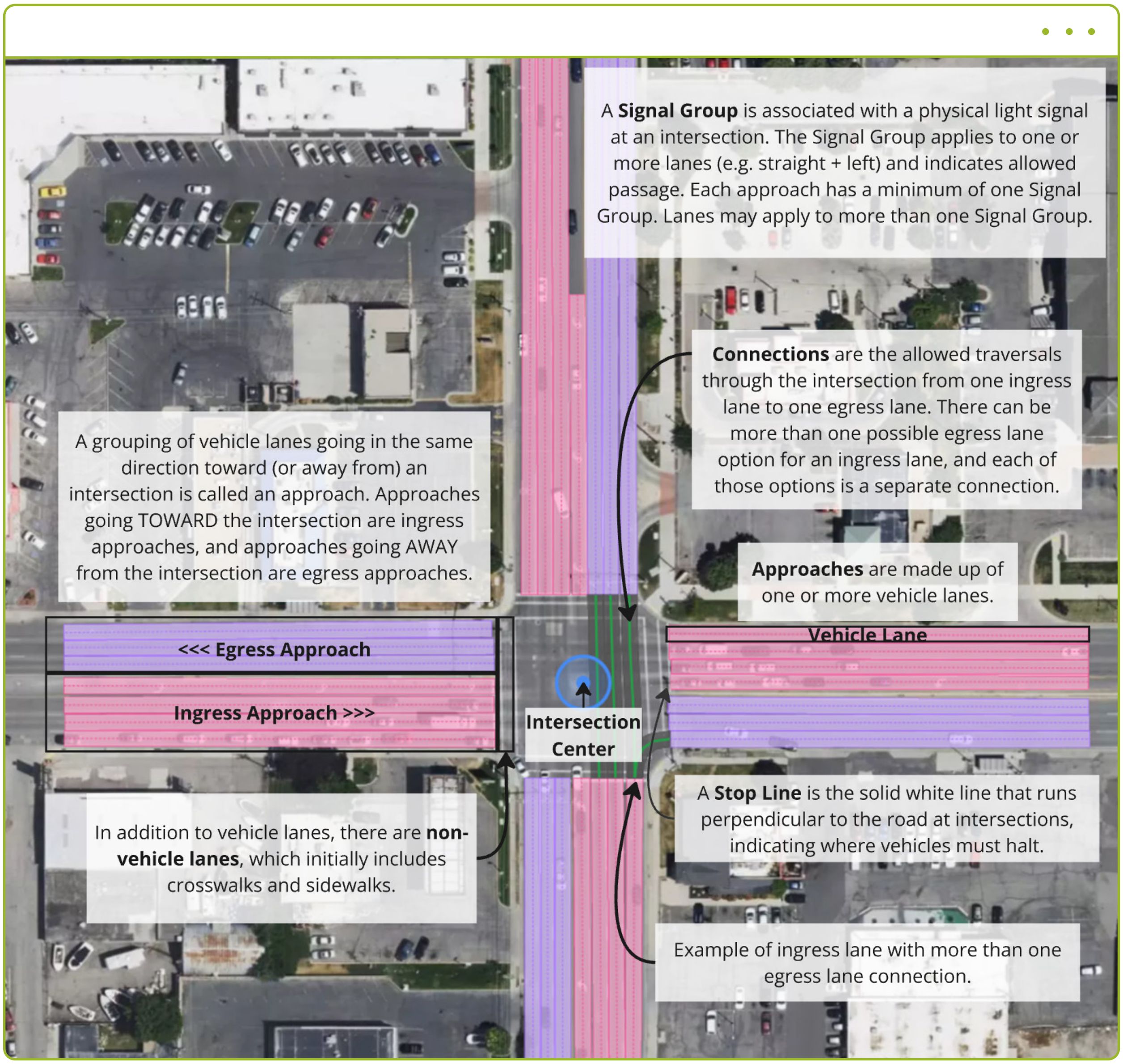

Figure 1: V2X-enabled intersection definitions.

Data received from traffic signals, vehicles, and the map geometry of intersections are all basic requirements for the standard operation of any connected intersection. These components are also necessary to enable CIMMS operation as they will contain vital information about whether the intersection is configured correctly, if drivers are behaving as expected, or if there are volumes of unsafe conditions that need to be addressed. Detection of these kinds of events stems from CIMMS reporting on a few key anomalies:

Alert Type	Description	Example	Suggested Resolutions
Data Degradation	Decline in volume and/or data points in traffic signal data.	1. The number of records received from the data source is lower than expected. 2. The signal status is missing from raw data payloads.	Fix network configurations to ensure devices are communicating correctly, ensure device firmware is updated, and/or power cycle devices regularly.
Traffic Signal Conflict	Conflicting signal groups (signal directions) appear active at the same time.	An east-to-northbound turn signal and a north-to-eastbound turn signal are green simultaneously. *See Figure 2*	Update or refresh signal state configurations.
Stop Line Violation	A vehicle appears to cross the stop line when the traffic signal is red.	This can trigger if a vehicle runs a red light or if the vehicle stops too far into the intersection such that they have crossed the stop line. *See Figure 3*	Refresh or update map data and intersection signage/markings. If configuration is correct, review intersection conditions for potential safety countermeasures.
Wrong Direction	A driver appears to be driving in the wrong direction when comparing vehicle and lane heading.	A driver enters an intersection via an egress lane and/or exits via an ingress lane. *See Figure 4*	Ensure the intersection map data and signage are correct.
Lane Connection Violation	As shown in Figure 1, ingress and egress lanes have defined connections to each other which indicates which from lane a vehicle is allowed to leave the intersection based on the lane they entered. If a vehicle does not follow this connection, this alert will be triggered.	A vehicle enters a left turn lane, but instead of turning left, the vehicle goes straight. *See Figure 5*	Signage and map geometry must be updated to ensure that there is no confusion about how to traverse the intersection. Recalibrate vehicle's onboard device in cases of GPS drift.

Each of the included intersection images show what the data represented and does not necessarily mean that these events are occurring at the intersection. This is one of the key aspects of CIMMS—to show what data the system is reporting and to attempt to identify desynchronization between data and roadway activity.

In each of these cases, it is especially helpful to know which areas are experiencing the highest volume of events so that these areas can be prioritized to fix. In the next section, we will discuss the CIRRUS approach to breaking down this data to provide actionable insights to users.

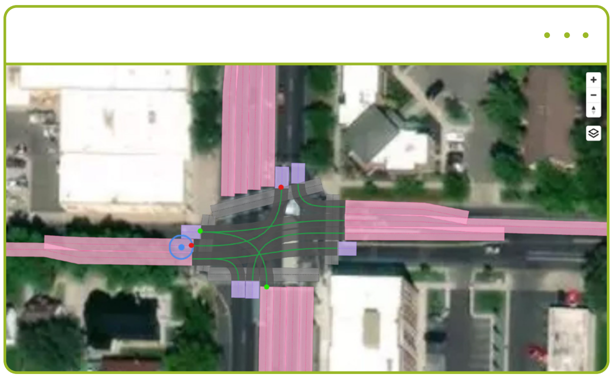

Figure 2: V2X-enabled intersection where conflicting signals are active simultaneously, possibly due to a signal configuration issue. Corresponding dots of the same color indicate the lane connection vehicles would take.

Figure 3: V2X-enabled intersection where a vehicle makes a left turn when the signal appears to not be green, possibly due to the signal showing red in the data but was green at the intersection, or map geometry being outdated, or the vehicle running a red light. Note: green lines indicate the signal is green and absence of a line between intersections indicates that the signal is red.

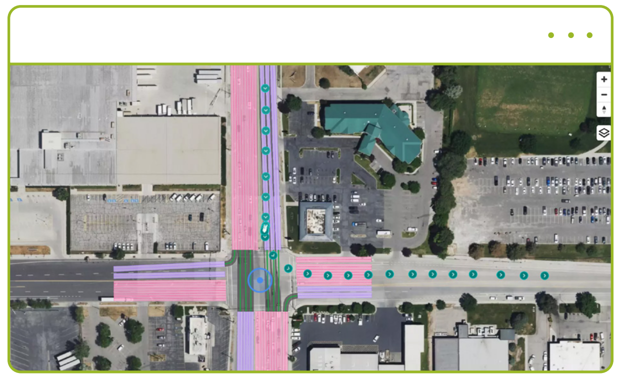

Figure 4: V2X-enabled intersection where a vehicle is driving in the opposite direction according to lane directionality. This could be the result of outdated map data, GPS drift (where the geolocation of the vehicle is not accurate), or the vehicle is traveling in the wrong direction. There could be cases where this is valid, however, if we consider that emergency responder vehicles will sometimes drive on the wrong side of the road to reach a location where an incident occurred.

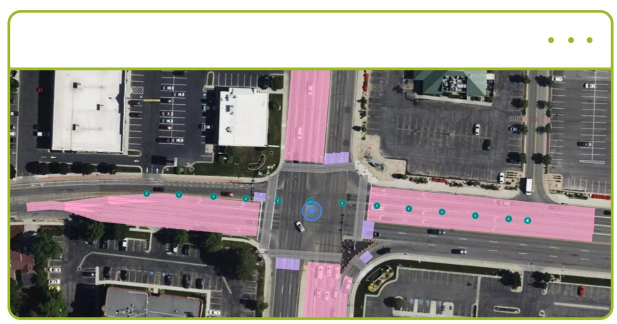

Figure 5: V2X-enabled intersection where a vehicle is expected to turn left given that it entered the intersection via a turn lane but instead proceeds straight through the intersection.

Connected Intersection technology is a great benefit to roadway safety by reducing congestion, crash probability, incident response time from emergency providers, and more.

Actionable Insights

Before integrating CIMMS, CIRRUS established monitoring for roadside devices that gather data at intersections. This "device health monitoring" keeps track of uptime and degradation of data or functionality for each device which acts as a first stage in an established hierarchy of alert generation. If devices are down or we are not receiving the data required to track downstream alerts, that will be captured at this step. This means that CIRRUS will not trigger CIMMS related alerts if a device is offline, thus reducing clutter and providing a more direct reason for issues that arise in the system. An example of what the output for these first stage alerts look like can be seen in Figure 6.

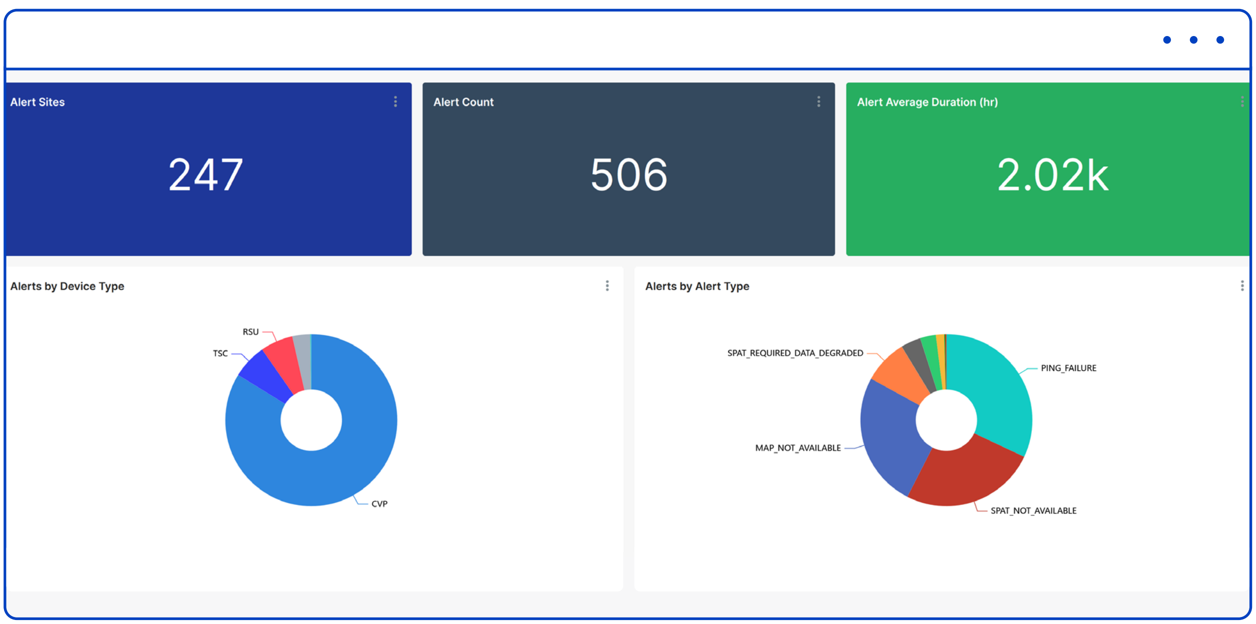

Figure 6: Device health alert dashboard for alerts that are currently active.

If a device does not have any alerts that would indicate it has experienced downtime or a degradation of its capabilities, then that enables monitoring of the next stages of our alert detection hierarchy, which is the site alerts.

Site alerts capture anomalies from the complete data received, which is exactly where the CIMMS alerts have been integrated. At this stage, different datasets are used together to discover data anomalies at the intersection. For instance, to capture Stop Line Violation alerts in a V2X deployment, the SPAT, MAP, and BSM data are all required to find an anomaly and generate an alert.

Figure 7 shows a high-level architecture diagram which indicates how the data flows through each stage of alert detection and then on into the actions/insights stage.

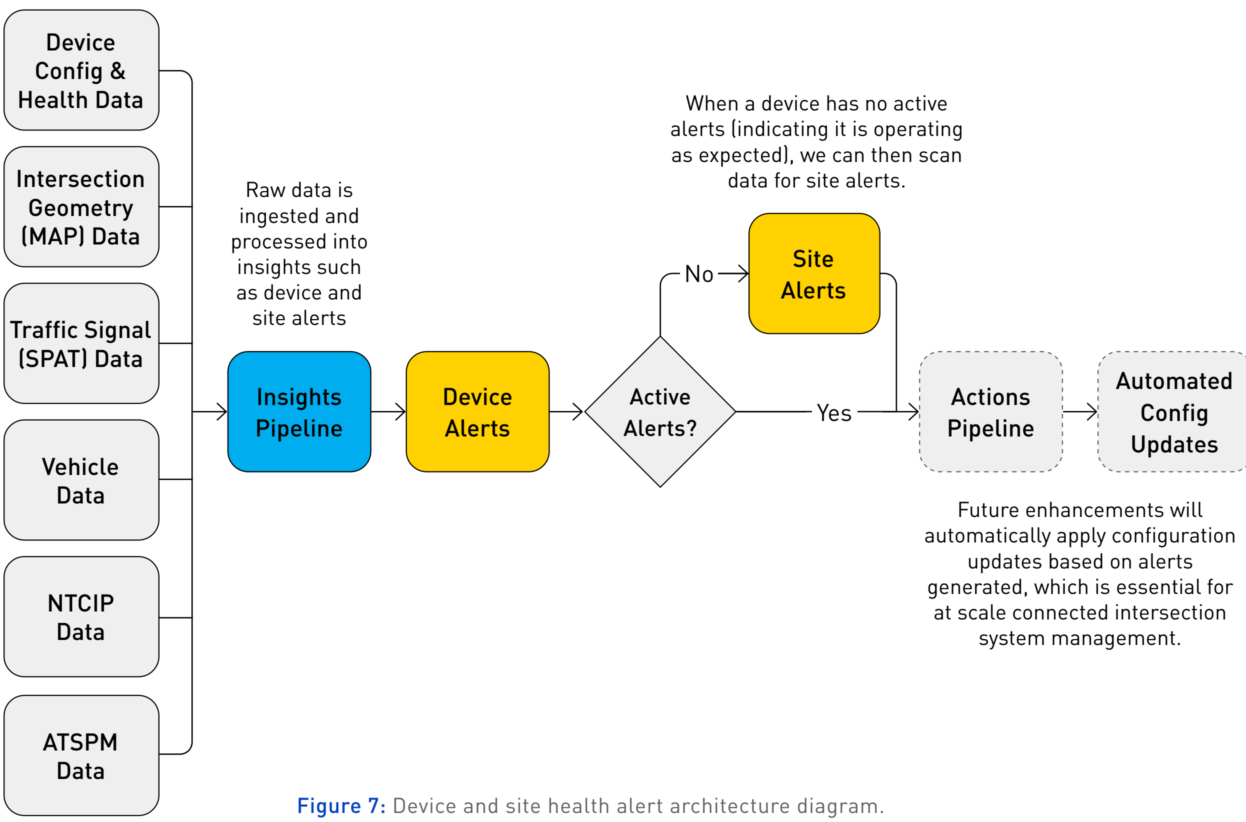

Figure 7: Device and site health alert architecture diagram.

When it comes to potential actions that can be taken in response to alerts, device-level resolutions may entail repairs, replacement, or reconfiguration, while those at a site level may indicate that there is a configuration conflict between devices. Thus we can provide a more complete picture of any issues occurring at an intersection and what to investigate or fix when these issues arise.

Interoperability and Scale

As mentioned previously, CIRRUS has implemented connected intersection monitoring in such a way that it can be applied to non-V2X edge hardware if network access is available to collect data from devices and sites. If data from vehicles, traffic signals, and intersection map geometry is available, then other connected intersection solutions and devices can be connected to the CIRRUS platform to ensure proper configuration and system management.

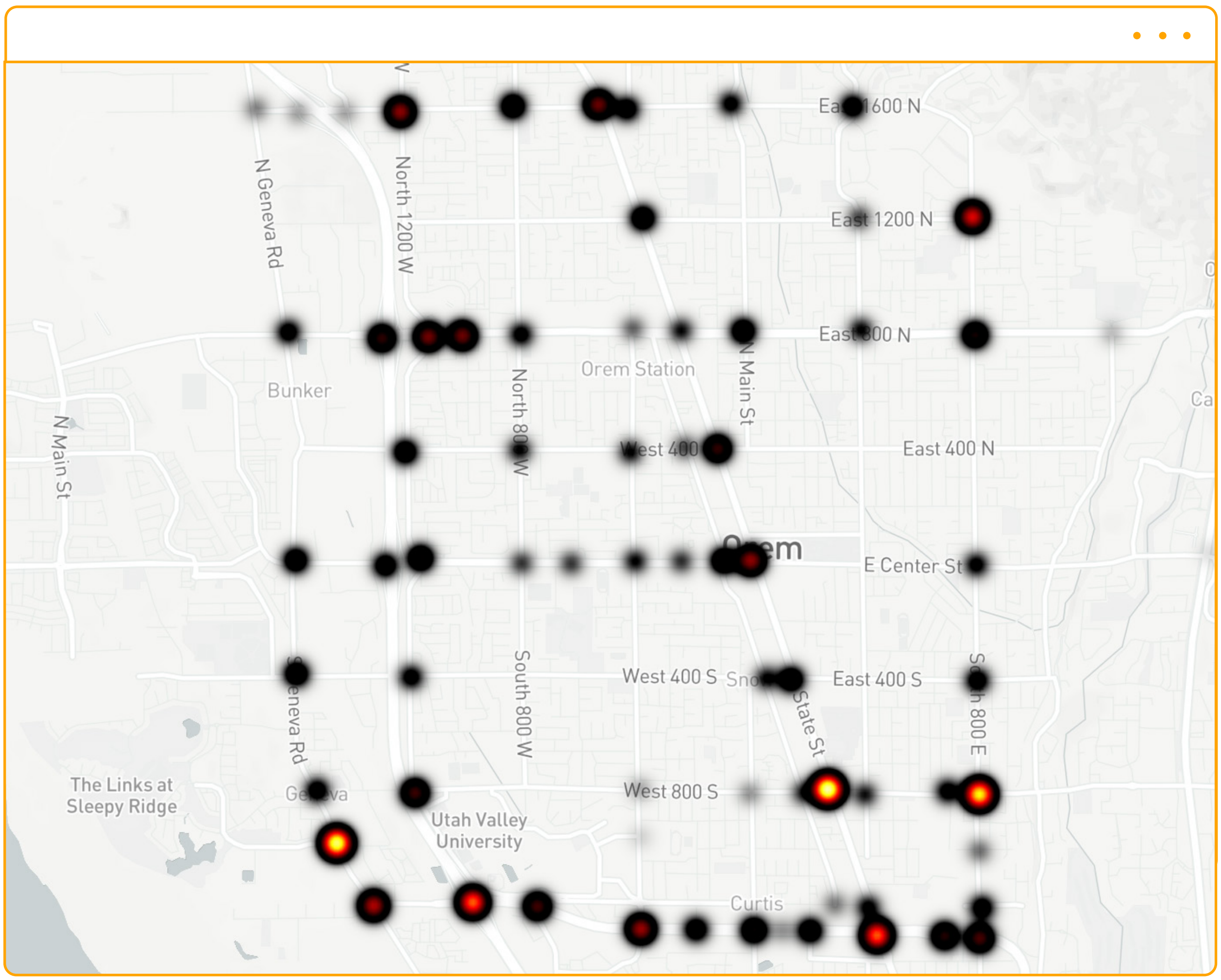

Figure 8: Utah's V2X deployment of Orem over a six-month period. Brighter red and yellow colors indicate higher volumes of alerts generated for the intersection in that area.

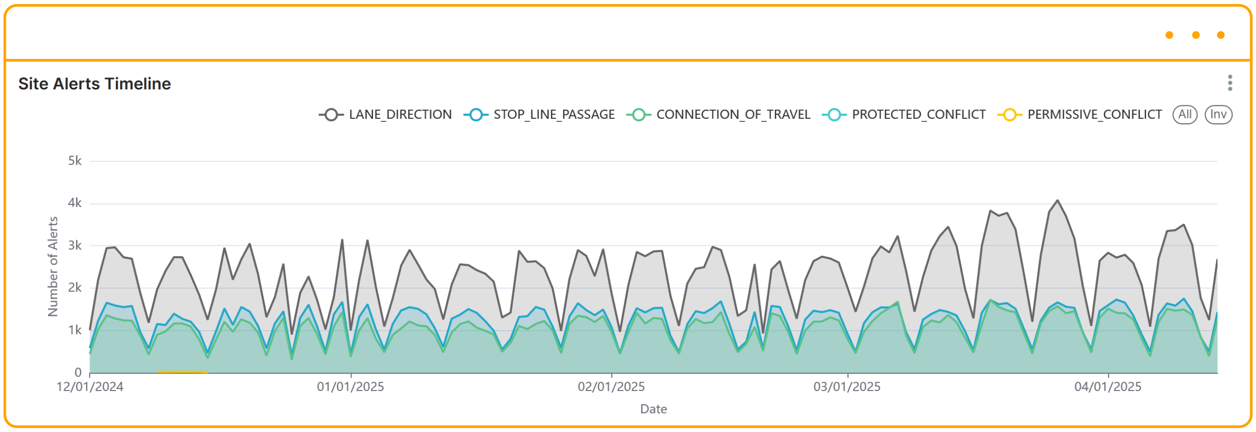

Figure 9: CIMMS alerts for Utah's V2X deployment over five and a half months.

From a scale perspective, CIRRUS deployed this solution in Utah for 400+ intersections for six months and identified thousands of issues per day within each of the categories mentioned above across the deployment. This was accomplished using a hybrid of real-time and batched alerting, where the former was used only for the most critical alerts that users need to know about instantly.

For instance, a single vehicle running a red light does not require immediate countermeasures (unless it results in a crash), but if every vehicle is running the red light, that may require diagnosis and a fix for a systemic issue. Also, when an intersection goes into flash-mode (where the signal lights flash yellow), it doesn't necessarily get immediate attention from infrastructure owners, so by batching the data and alert generation, we optimize resolution timelines and priority levels.

Ultimately, this approach created the cost-effective application of intersection monitoring to expanded deployments where all that is needed is to register a device in the CIRRUS system and the data flows through the alerting architecture the moment the device comes online. This means that monitoring the integrity of data at the intersection can be ubiquitous in the future of roadway connectivity.

CIMMS provides further coverage to issues that may require reboots or configuration changes for a greater variety of base issues that can scale with growing deployments.

Outlook

The future vision of CIRRUS CIMMS is to extend into automation of actions to resolve, as seen at a high level in the architecture diagram in Figure 7. CIRRUS already does this for devices that experience downtime due to network failures or other factors. For example, if CIRRUS is not receiving SNMP data from a device for a certain period, then a command will be sent to either reboot or power cycle the impacted device. If data begins to flow from the device again, then no further action is necessary, but if that does not fix the issue, a second attempt is made.

If the automated response still does not fix the problem, then a notification is issued for someone to take more directed action. This saves a lot of time for those servicing and fixing these devices as they no longer need to spend time resolving the simpler issues that can occur with a connected intersection deployment. The addition of this feature to the CIMMS alert pipeline provides further coverage to issues that may require reboots or configuration changes for a greater variety of base issues that can scale with growing deployments.

About CIRRUS by Panasonic

CIRRUS by Panasonic is a division of the Panasonic Corporation of North America's Smart Mobility Office. Formed in 2017, our connected vehicle applications are among the first to shift signal priority applications from legacy hardware units to cloud technology.

The CIRRUS platform enables instant and safe communication between vehicles, infrastructure, intersections, and the operations teams who manage them. Our optimized, patent-pending algorithms incorporate data from edge devices, external systems, and cloud products for a scalable, complete, end-to-end solution.

Learn more at **https://mobility.na.panasonic.com/CIRRUS**.

About the Authors

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As an Analytics Engineer on the Data Science and Analytics team at Panasonic Smart Mobility, Matt is dedicated to turning data into insights. He has defined and built critical data systems that service customer needs including data marts, real-time event detection, system health monitoring, and dashboard solutions. Insights he has provided have saved companies millions, helped improved roadway safety, helped target products toward the right audiences, and informed product direction. Matt has proven experience in data modeling, discovery, curation, visualization, analysis, and storytelling, as well as scripting, automation, process development, cloud infrastructure, and database technologies. He has worked in the data space since 2016 and holds a B.S. in Computer Science and Cognitive Psychology from Northeastern University.

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