PIMA COUNTY

# Smart Transportation Systems and Supporting Data Networks

February, 2020

There is much conversation regarding smart transportation systems, their relation to connected and autonomous vehicles, and the communication and other infrastructure needs local communities should consider in order to facilitate and accelerate the adoption of these technologies. This review aims to provide context to this conversation so as to concentrate limited local resources on strategies that will provide the greatest potential return in optimizing local transportation system performance.

Strategies fall into three basic categories: those that will be implemented by the private sector through standards promulgated by national entities such as the U.S. Department of Transportation (USDOT); strategies that cannot be implemented until such time that other technology has been deployed at a large scale; and lastly, strategies that can be implemented today by local communities with existing technologies. This review will concentrate on the latter all while ensuring that communication and other capacity needs of future strategies are considered as part of any infrastructure investment.

**Smart Transportation**

Smart transportation refers to the integrated application of modern technologies and management strategies to optimize transportation systems. These include:

- Mobility on demand (MOD) technologies assisting travelers in reducing travel time, system costs, fuel consumption and enhancing safety
- Intelligent technologies optimizing signal timing and other infrastructure based on need such as ramp metering, transit signal priority and lane shifting
- Real-time transportation system updates to vary speed limits or road closures based on weather or emergency conditions
- Improving freight efficiency
- Rendering the multi-modal public transportation more convenient and reliable

**Connected and Autonomous Vehicles**

The Connected Vehicle program led by the USDOT is working with transportation agencies, vehicle and device manufacturers to test and evaluate technologies that will enable cars, buses, trucks, trains and infrastructure to “talk” to one another so as to optimize both mobility and safety.

Connected vehicles will have significant advantages over technologies now becoming commonplace in new vehicles, such as radar, LiDAR, cameras, and other sensors. Connected vehicle technologies and applications have a greater range than on-board vehicle equipment, which will allow for receiving alerts of hazardous situations much earlier, providing more time to react and prevent a crash. Also, connected vehicle technology doesn't depend on “line of sight” communications to be effective, unlike radar. So if a car is braking hard on the other side of a hill due to an obstruction, notifications would be sent to following vehicles who cannot see or who are not aware of the dangerous situation developing. Connected vehicle technology will likely become standard equipment on all vehicles to supplement on-board sensors and some of these are already appearing in some new European cars where manufacturers are pushing navigation app traffic safety alerts among cars of the same brand. It is likely that communication standards among different vehicle manufacturers will be developed and promulgated by the National Highway Traffic Safety Administration in the U.S., working in concert with analogous international organizations. Connected vehicle communications are currently being tested on 4G networks and Dedicated Short-Range Communications. However, up and coming 5G networks will be able to provide the speed, bandwidth and low latency requisite to further optimize connected vehicle applications without requiring separate dedicated communication systems be installed along roadways.

Autonomous vehicles do not require connected vehicle technology since they must be able to independently navigate the road network using on board sensors processed through artificial intelligence algorithms. However, connected vehicle technology brings the same benefit to autonomous vehicles as to driver controlled vehicles and so will be able to benefit from same. As such, autonomous vehicles are not a separate technology class from a transportation network operational management perspective, although as they begin to proliferate, it may make sense to allocate roadway resources to optimize mobility such as dedicating the leftmost lane of multi-lane roadways to autonomous vehicles to take advantage of platooning and other automated technologies that aim to minimize vehicular roadway footprint while increasing safety.

**Communication Needs and Options**

The communication needs for smart transportation and connected vehicles have been referred to as vehicle to vehicle (V2V), vehicle to infrastructure (V2I) and vehicle to everything (V2X) typically connecting to the internet of all things (IoT). Regardless of the nomenclature, the purpose of communication is to link two or more data elements to facilitate smart transportation strategies.

Some communities are exploring sensors imbedded in the roadway to provide data as to number of vehicles, speed and direction. However these types of sensors have limitation such as cost, maintenance and functionality limited to the parameters they were designed to track. An alternative solution is to harness smart communication sensors already ubiquitous across the transportation system: smartphones and vehicle navigation apps. These can not only report base sensory information provided by roadway sensors such as location, speed, direction but in addition, the active navigation system capability can provide two-way sensors and analyses to feed an entire suite of smart transportation system technologies. From a communication perspective and since the data uploaded from and to MOD navigation apps require low bandwidth, these can be adequately executed with the standard 4G SIM connections currently in use within smartphones and connected vehicles. Hence smartphones or connected vehicles can report travel patterns to a traffic operations system or a cloud-based navigation app to assist in optimizing the transportation system for all travelers. GoEzy, Google Maps, Waze and HERE are basic examples of these types of apps, though these currently have very limited scope when considering the overall potential of a comprehensive MOD platform.

The value of optimizing mobility through the use of smartphone and similar device apps is reinforced by USDOT. The Federal Highway Administration Center for Accelerated Innovation is advocating for platforms using smartphones to manage transportation operations since “Crowdsourcing turns transportation system users into real-time sensors on system performance, providing low-cost, high-quality data on traffic operations, roadway conditions, travel patterns, and more.” Crowdsourcing is the practice of obtaining inputs into a task by enlisting the services of a large number of people, typically via the internet and as related to smart transportation, running a MOD app on a smart device.

While any mobility app could be configured to communicate with infrastructure, it is hoped that USDOT will eventually promulgate communication standards for connected infrastructure, such as traffic signals, so that all commercial apps can read and consume the data to optimize navigation and MOD apps. Shorter term, however, and since we do not yet have a regional platform to read and process traveler data, we still need to have our signalized intersections read travelers to optimize signal timing.

To this end most signalized intersections have at least two locations where they can read travelers. The first is an advance detection loop, typically imbedded in pavement to know when vehicles are approaching the intersection and the second comprises detection at the intersection proper through an imbedded loop or video camera. The advantage of video over imbedded loops is that it can differentiate between mode, type of vehicles and track turning movements. While the detectors can effectuate signal phase and timing changes in real time, the balance of the travel data can be used for analysis of patterns leading to optimizing timing across corridors at different times of day. Miovision, installed at County signalized intersections, provides a comprehensive set of analytics to assist in optimizing intersection performance. To output these analytics data as well as signal controller self-reporting errors, traffic signals require a communication device to transmit back to the system operator for analysis. Since high resolution intersection video requires higher bandwidth and speed and remote programing of controllers requires lower latency than can reasonably be accommodated with 4G devices, a network connection technology with higher bandwidth and lower latency is required to connect traffic signals.

However, and in addition to traffic signals and traveler smart devices, it is important not to lose sight that certain additional roadway-related sensors may be needed. These include rain and streamflow gauges, to trigger when to provide at grade crossings closure inputs to navigation/MOD apps; and emergency pre-emption to clear roadways for emergency responders.

**5G Infrastructure**
5G is the fifth generation of mobile networking which will increase average speed from 10Mbps up to 10Gbps, reduce average latency from 50ms to 1ms and increase bandwidth significantly over 4G networks. These enhancements will optimize communication capabilities across a range of functions, including providing the capacity and reduced latency required to connect traffic signals, as well as provide for connected vehicle communication. Aside from speed, bandwidth and low latency, 5G will allow for many more device connections than 4G networks. A prime benefit of 5G is that it offers carriers with more airwave options than 4G, notably by opening up high-band short-range waves in addition to the current 4G band-widths.

Low-band 5G operates in frequencies below 1GHz. These are the oldest cellular and TV frequencies. They go great distances, but are narrow in channels, and many of those channels are being used for 4G. So low-band 5G is slow—it acts and feels like 4G for now. The low-band 5G channels currently in use average around 10MHz in width. In the U.S., AT&T and T-Mobile are currently operating in this space.

Mid-band 5G is in the 1-10GHz range. That covers most current cellular and Wi-Fi frequencies, as well as frequencies slightly above those. These networks have a range of about half a mile and carry most current 5G traffic. Most other countries have offered around 100MHz to each of their carriers for mid-band 5G. Here in the U.S., only Sprint (FCC approved to be merged with T-Mobile under the T-Mobile name) has the available spectrum for this approach, although there may be a new auction at the end of 2020 that could offer up more airwaves.

High-band 5G, or millimeter-wave, is the newest space, comprising airwaves in the 20-100GHz range. These very short range airwaves have not been used for consumer applications before and often do not reach beyond 800 ft. However, this space contains vast amounts of unused spectra which means very fast speeds using up to 800MHz at a time. AT&T, T-Mobile, and Verizon are currently using some of this space. These bands have also been used for backhaul, connecting base stations to remote point links. However they haven't been used for consumer devices before. Millimeter-wave signals also drop off faster than lower-frequency signals and so the massive amount of data they transfer will require more connections to landline internet. To use this space, many small cell, lower-power base stations (generally outputting 2-10 watts) rather than fewer, more powerful macro cells (which output 20-40 watts) will be required to offer the multi-gigabit speeds that millimeter-wave networks promise. Carriers have already installed small cells in many major cities to increase 4G capacity. This includes Tucson where AT&T has submitted over 278 4G small cell permit applications and Verizon which has submitted applications for over 30 5G installations in the downtown area, 4$^{th}$ avenue and the university rectangle. Modifying small cells from 4G to 5G only requires attaching an additional radio onto an existing site.

It is expected that the transition from 4G to 5G will happen organically, driven by private sector carriers as has occurred with prior communication network generational upgrades.

**Smart Transportation Network Readiness for Pima County Government**

As we prepare to implement a smart transportation network, the greatest need as discussed above is signalized intersection communication. To this end, we need to connect signals with sufficient bandwidth, speed and low latency to both stream high resolution video and send reliable protocols to signal controllers for timing adjustments. Also needed is enough capacity for eventual crowdsourced adaptive signaling driven by a MOD app platform, thereby moving travelers in coordination with signal inputs so as to maximize overall transportation system performance. While a minimum of 20 Mbps up and down is an appropriate design parameter for use today, the current selection of network technology for the next decade should consider capacity for increased bandwidth.

Currently deployed technologies having the capacity, latency and speed requisite to fulfill signalized intersection needs for current video, analytics and readiness for MOD platform deployment include mid- and high-band 5G as well as optical fiber. Network infrastructure architecture choices include a Pima County communication network, returning 5G or optical signals to a point source within the County network, or a private communication network, relaying encrypted data from each intersection to the internet via a private carrier.

It is also important to note that for smart transportation to perform regionally, a network will be needed to connect the regional traffic signals to a regional MOD platform. Currently, regional signals are connected through the Regional Transportation Data Network (RTDN) operated by Smartwave and contracted through the City of Tucson. This network, however, is failing at multiple points and is in need of replacement. Regional connectivity of the RTDN connected traffic signals occurs through the Intelight Maxview platform, running on a City of Tucson server and providing data and tools for regional signal coordination. Therefore any new County network architecture will still require for County signal data and analytics to return to a Maxview server connected to other regional Maxview servers.

**Recommendation for Pima County Government**

In order to accelerate smart technologies readiness as well as optimize County current operations with better communication network connectivity, it is recommended that a procurement effort be undertaken to connect all County signalized intersection with carrier-controlled mid- or high-band 5G or optical fiber connections.

As all County signalized intersections are supported by Miovision technology, the successful communication carrier would be responsible for providing speed, latency and bandwidth specifications for internet intersection connection to the Miovision cloud.

This configuration will allow the County to connect a Maxview server to both the Miovision cloud and to the other regional Maxview servers. This will provide County access to Miovision analytics, County signalized intersection controllers and cameras, preserve the regional Maxview traffic signals connections, and provide connection capacity and capability for a future regional MOD platform. In so doing, the County will be best positioned to continue incorporating smart transportation technologies as they become available.