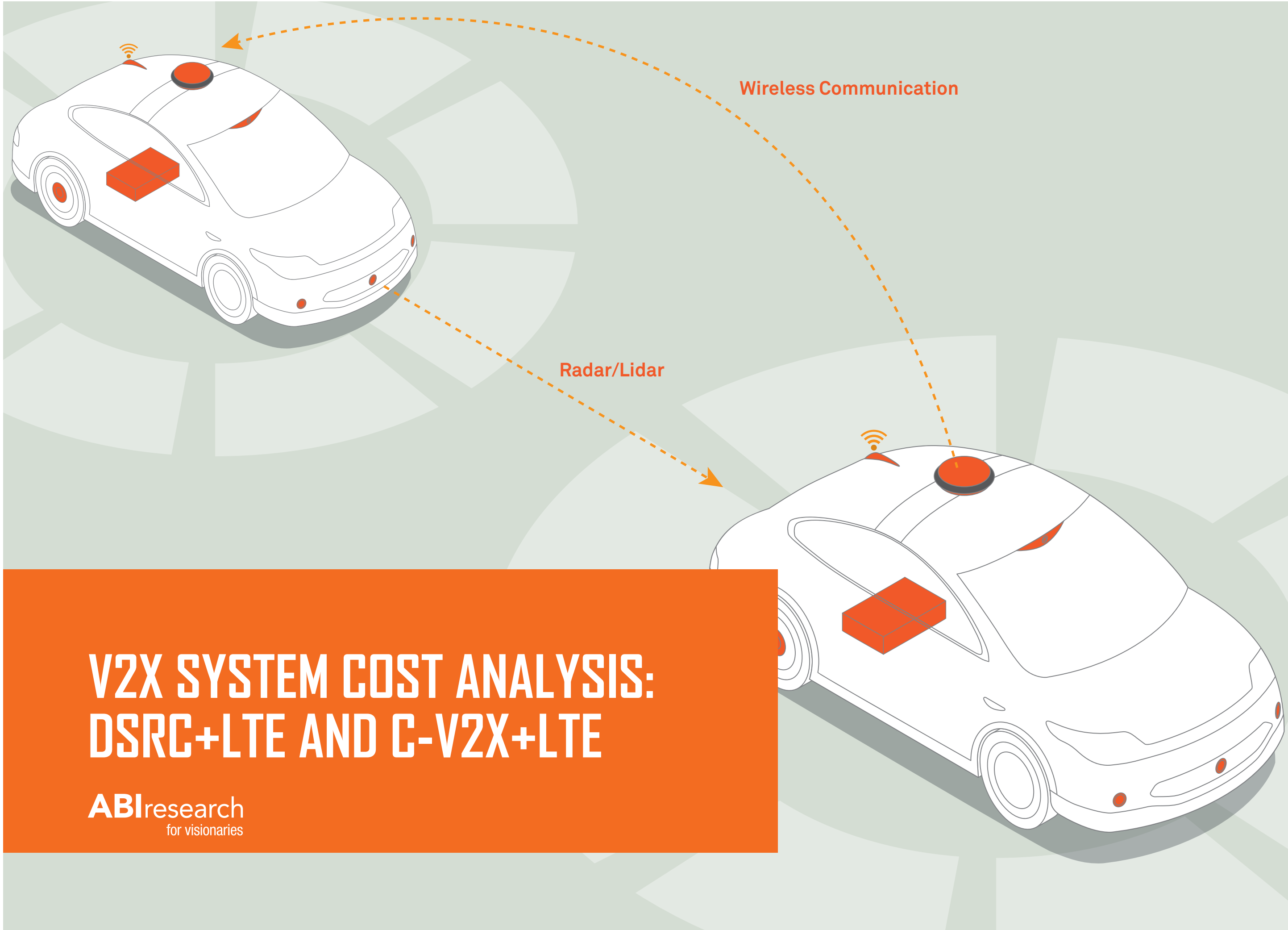


# V2X SYSTEM COST ANALYSIS: DSRC+LTE AND C-V2X+LTE

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## INTRODUCTION

The concept of vehicle-to-vehicle (V2X) communications is well established in the automotive industry, and in its most basic sense refers to the near-instantaneous sharing of safety-relevant data between vehicles to support obstacle detection, collision avoidance, and cooperative mobility more generally. In the context of ADAS and autonomous driving, V2X is intended to support and complement on-board ranging sensors such as camera, radar, and LiDAR by providing non-line-of -sight (NLOS) capabilities, in effect giving the vehicle the ability to "see around corners."

This analysis will detail the cost differential between two distinct approaches to V2X communications:

- Dedicated short-range communications (DSRC) + LTE
- Cellular V2X (C-V2X) + LTE

The long-term expectation from stakeholders in both of these solutions is for V2X functionality to be incorporated into the broader telematics control unit (TCU) architecture. Therefore, this analysis will consider the cost effectiveness of both DSRC and C-V2X within the context of a broader TCU featuring LTE cellular connectivity.

## Definitions

**DSRC**: DSRC is a wireless communication technology designed specifically for automotive applications. The IEEE 802.11p Wi-Fi standard is an ad-hoc networking framework that operates in the 5.9 GHz range and is effective at distances of around 1 km for LOS applications and 300 m for NLOS applications, and is particularly optimized for connections between vehicles moving at high speeds. By sending basic safety messages (BSM), including vehicle position, speed, size, acceleration, braking status, and other safety-relevant information, DSRC targets use cases such as collision avoidance, queue warnings, and speed harmonization.

**C-V2X**: Cellular V2X is a comparatively recent technology, and is subject to a high degree of misunderstanding. Release 14 from the 3rd Generation Partnership Project (3GPP) specified LTE-D2D for automotive applications: a PC5 radio interface with distributed scheduling, enabling vehicles to be connected without sending traffic over the network or requiring the network to schedule connections. As with DSRC, messages are transmitted in the 5.9 GHz spectrum, with the limited available bandwidth focusing the applications on safety use cases, with some scope for non-safety services. While D2D connections will not be made over the network, stakeholders in C-V2X look to eventually enable connections over the network, with 5G network slicing technologies providing the required QoS with respect to bandwidth, latency, and separation of mission-critical and non-mission-critical traffic. This long-term vision will see the introduction of safety-related services beyond the scope of D2D or DSRC V2X, including massive sensor data sharing for collective perception and remote operation. Vendors within the DSRC ecosystem also look to support coexistence with 5G automotive services in the future.

## V2X Use Cases and Further Assumptions

This analysis will deliver a like-for-like cost comparison between a DSRC+LTE and C-V2X+LTE architecture targeting the core V2X safety use cases that are common to both technologies. While stakeholders in the C-V2X space emphasize compelling non-safety use cases enabled by their technologies, this is beyond the scope of this analysis, as are "next-generation" safety services expected to be enabled by cellular connections over an automotive slice of the network. This analysis also makes two further assumptions.

### *Mission Criticality of V2X*

V2X will be a mission-critical technology, implying a high level of system integrity.

### *TCU Integration Assumptions*

The short-term focus for the V2X industry is to ramp up penetration in order to deliver the critical mass necessary for a reasonable level of service. For DSRC, this means that the technology is typically made available in standalone modules or on-board units (OBU) that can be readily scaled. Although there is considerable scope for integration with the TCU, OEMs are reluctant to integrate at this stage, for fear that future requirements will outstrip the integrated system. On the C-V2X front, the principal vendor in this space, Qualcomm, has yet to begin sampling its C-V2X 9150 chipset, and has not made its C-V2X reference design public.

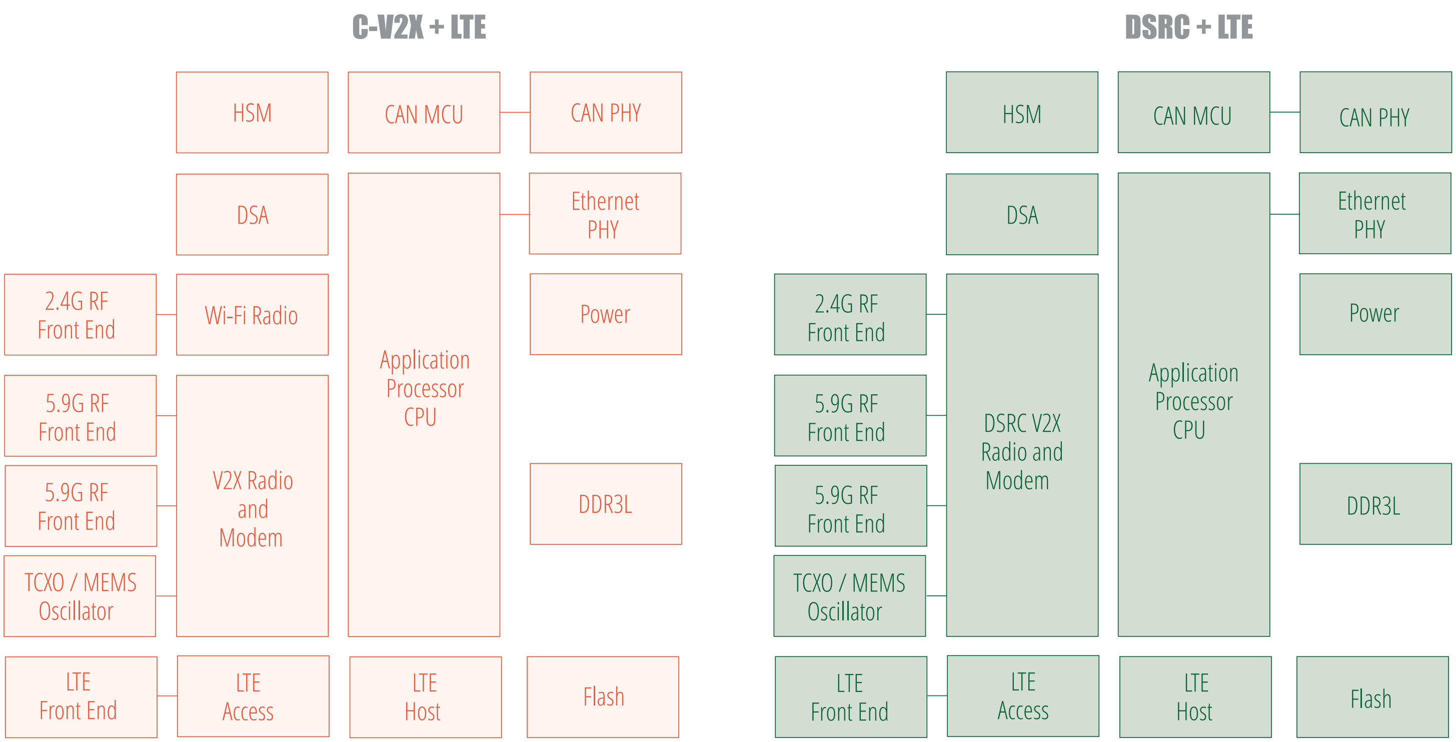
Nevertheless, integration with TCU is the medium- to long-term ambition for vendors in both ecosystems. Therefore, with input from stakeholders in both the DSRC and C-V2X markets, ABI Research has developed the most feasible system designs for both approaches.

## SYSTEM COST COMPARISON

### System Architecture Overview

Figure 1 illustrates two example V2X architectures, one incorporating DSRC+LTE and the other C-V2X+LTE.

*Figure 1: V2X System Architectures – C-V2X+LTE and DSRC+LTE* ***(Source: ABI Research)***

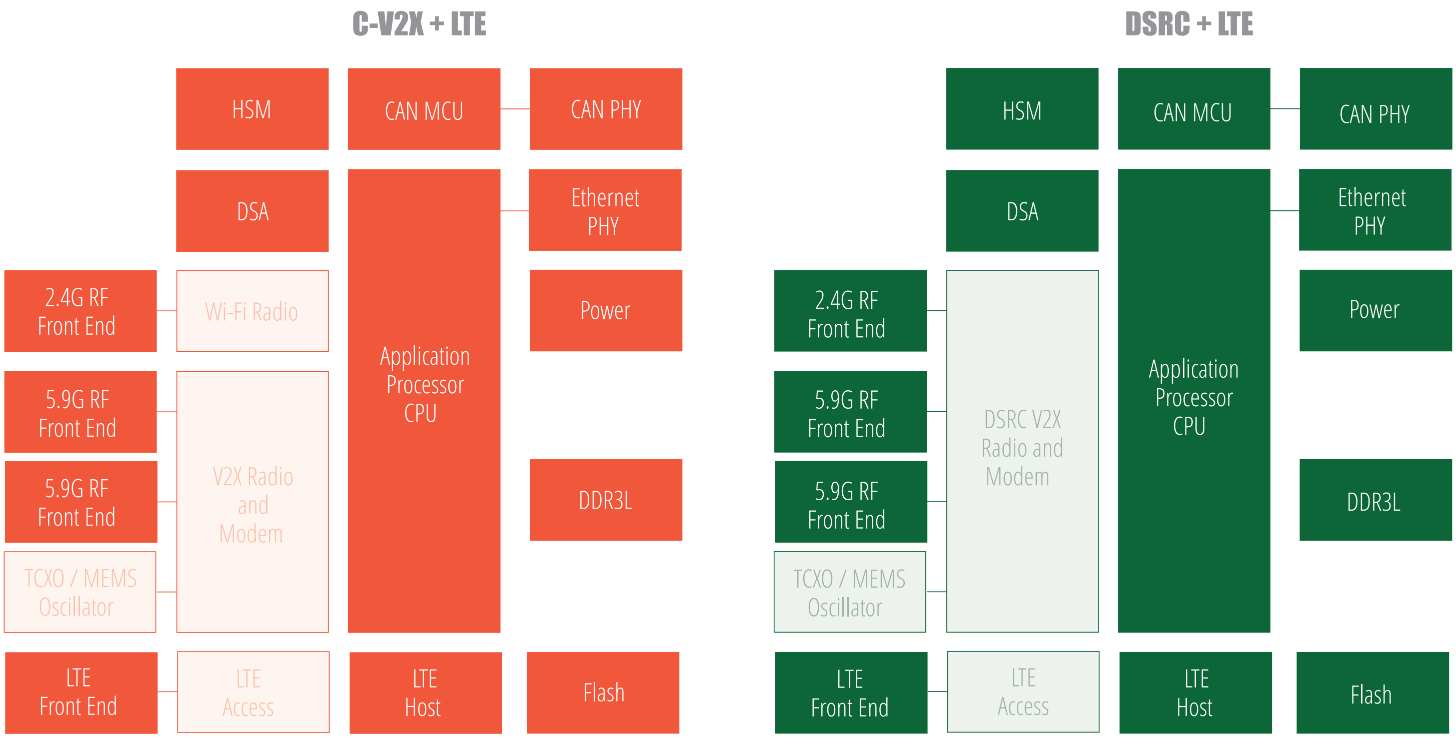



Both systems have very similar architectures, which is perhaps unsurprising given that C-V2X has come to heavily emulate DSRC in order to schedule connections without relying on the network. For both approaches, integration into a TCU yields considerable cost advantages, provided that the antennas can support RF coexistence for 5.9 GHz DSRC/D2D/Wi-Fi, 2.4 GHz Wi-Fi, and 1.6 GHz GNSS. Other areas of commonality between DSRC+LTE and C-V2X+LTE include the following:

- **Periphery**: Both architectures share a common RF frontend and requirement for memory, power, in-vehicle networking, *etc*.
- **Security Hardware**: DSRC and C-V2X have identical security requirements from a hardware and algorithm perspective, most likely taking the shape of a standalone automotive-grade HSM linked to the application processor (AP), or perhaps integrated inside the AP.

- **CAN Bus Subsystem**: Access to the CAN bus is essential for actuation.
- **Application Processor and LTE Host**: DSRC and C-V2X approaches both require secure application processors and an LTE host.

*Figure 2: Architectural Commonalities – C-V2X+LTE and DSRC+LTE* ***(Source: ABI Research)***




Setting aside the areas of commonality and the shared opportunities for cost savings when incorporated into a broader TCU architecture, this analysis will now identify the key differences between the two architectures, the factors driving differentiation, and the implication on the total cost of implementation.

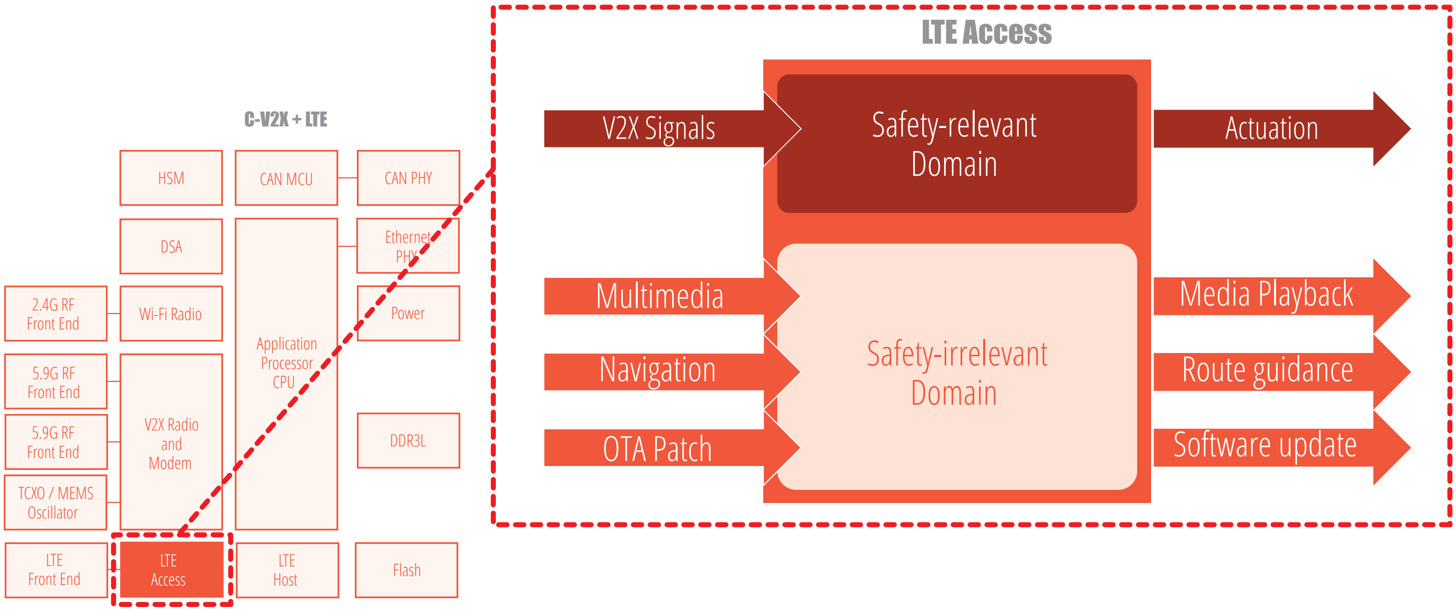
## ARCHITECTURAL DIFFERENCES AND COST IMPACT

### LTE Access

DSRC is a Wi-Fi standard (IEEE802.11.p), which means that the LTE access has no safety-relevant role within the V2X system. OEMs, or more specifically TCU Tier One integrators, will therefore be able to source "off-the-shelf" LTE modems presently in use in millions of connected cars. In C-V2X systems, however, D2D or sidelink transmissions use uplink resources from the physical layer of a dedicated cellular modem, making the LTE modem a safety-critical component. A separate LTE modem packaged in the same device is required to ensure that D2D transmissions have access to the necessary resources, since LTE transmissions are scheduled by eNB, which has no visibility on D2D scheduling. ABI Research's assumption from the outset of this analysis is that V2X will play a mission-critical role, either as a support for advanced driver assistance systems (ADAS) or as an element in a broader autonomous driving system. This has the following implications for C-V2X:

- **Functional Safety/System Integrity**: Assuming mission criticality for V2V as a safety-relevant technology, V2X systems are expected by most implementers to carry at least an ASIL B functional safety requirement when the system is intended to support actuation of the brakes, steering, or accelerator (this depends heavily on the overall architecture for the electronic/electrical (E/E) item that V2V is designated to support). For DSRC architectures, this means no functional safety requirement with respect to the LTE access because it has no relevance to the expected performance of the V2V system. For C-V2X, however, it will be necessary to develop an LTE modem that can guarantee separation and non-interference between non-safety-relevant functions (e.g., connected infotainment) and the safety-relevant V2V application, in accordance with the ISO 26262 functional safety standard. This can be achieved through either software techniques guaranteeing safety-critical access to resources or through physical separation of a safety-relevant domain. If C-V2X implementers further look to use the LTE clock as a reference, the whole LTE modem becomes mission-critical.
- **Automotive-Grade Resilience**: While functional safety concerns the guarantee that an E/E system will behave as expected, it is also important that the constituent components of the V2V system are sufficiently robust to survive the harsh automotive environment. The state-of-the-art AEC Q100 standard sets out requirements for resilience to dust, moisture, EMI, and extremes of temperature according to five different grades. Most implementers target Grade 0 or 1 for "under-the-hood" systems, meaning reliable performance from -40°C to +125/150°C, with telematics functions typically requiring Grade 2 certification (-40°C to +105°C) for their constituent components. This will undoubtedly add further cost relative to cabin-grade LTE currently featured in the connected infotainment head unit. In early implementations of C-V2X, this will further the cost difference relative to DSRC; however, going forward, OEMs are likely to include a highly robust LTE connection for over-the-air (OTA) and sensor-data crowdsourcing applications, which will add cost to TCUs featuring both C-V2X and DSRC.

*Figure 3: Separation of Safety-relevant and Non Safety-relevant Traffic in C-V2V* *(Source: ABI Research)*




Based on historic ruggedization of components for automotive E/E systems, ABI Research expects functional safety validation and automotive-grade certification to add between US$3 and US$5 of cost for C-V2X architectures relative to DSRC.

## Synchronization and Clock Sources

Accurate positioning and timing is the cornerstone of an effective V2X system, with synchronization between domains being foundational. Cumulative timing and frequency drifts between vehicles will impair the ability of the C-V2X modem to lock onto the C-V2X transmissions of other vehicles. This can prove even more problematic in vehicles moving at speed. C-V2X relies heavily on accurate timing and precise frequency synchronization in order to deliver an effective service.

In most circumstances, this can be provided by GNSS satellites, with coverage from around six satellites being required. However, there are some environments in which GNSS coverage is poor, particularly in dense urban canyons and tunnels. Given that this analysis assumes V2V as a mission-critical technology, a C-V2X architecture would need to provide accurate synchronization in these environments. One approach would be to synchronize according to a cellular basestation; however, two vehicles "locked-on" to two different basestations will have a cumulative drift likely to exceed the required frequency accuracy of 0.3 ppm as detailed in 3GPP TS 36.101. Therefore, in order to guarantee required QoS, each user must synchronize in accordance with their own clock source, mandating the fitment of a high-accuracy oscillator; for example, a 0.1 ppm MEMS TCXO. At the time of writing, no automotive-grade variants of such oscillators exist on the market; however, anonymous input from two vendors suggests that, at scale, an automotive-grade 0.1 ppm TCXO would carry an ASP of around US$8 to US$10.

## The Conventional Cellular Royalty/Licensing Business Model

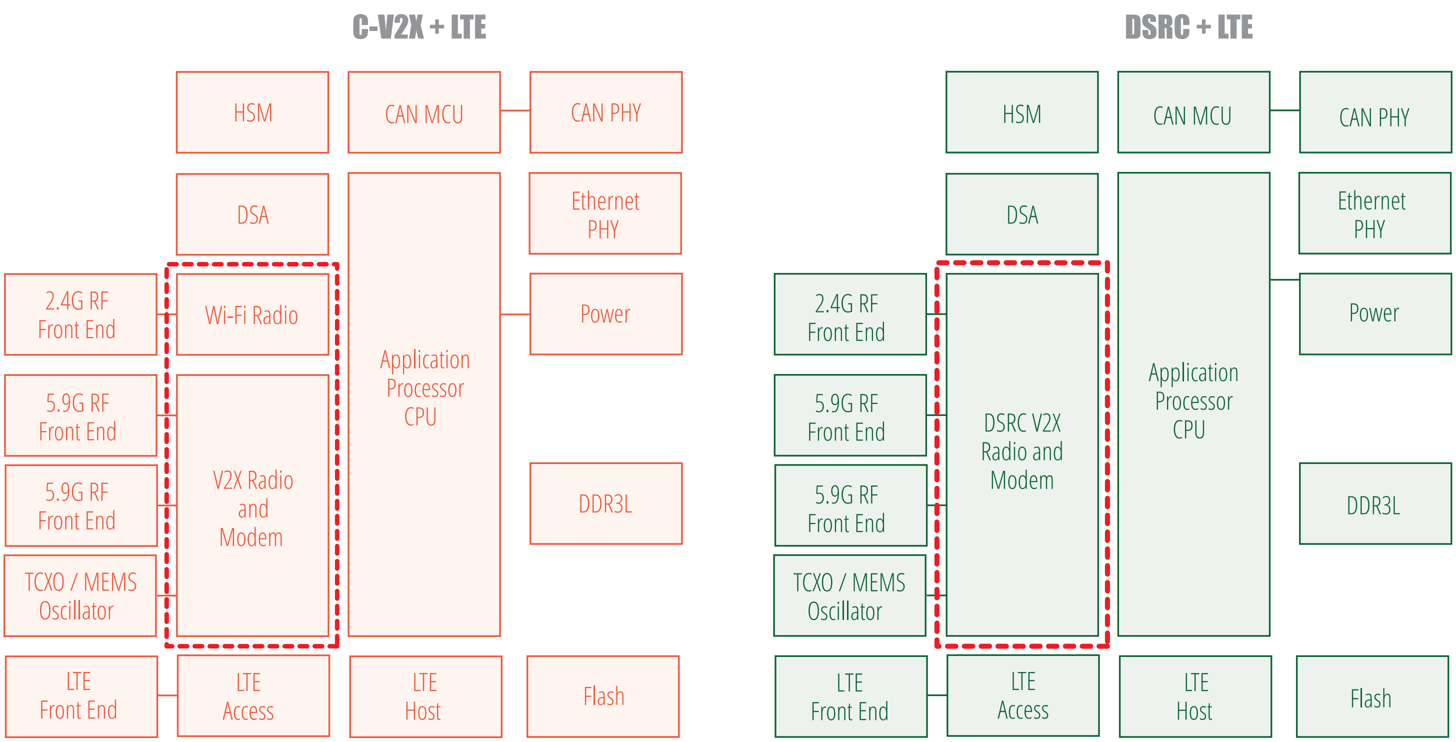
Typically, cellular chipset vendors operate according to a licensing business model, in which the customer is provided with a technology design that they then manufacture (in cooperation with various partners). In the automotive context, the OEM customer agrees to pay a royalty for each unit (in this case a V2X system) sold, typically up to around 5% of the total unit price. This could add between US$0.50 and US$1 to the cost of each C-V2X system.

## The Potential for Re-Use of the DSRC Wi-Fi Radio

Equipping the TCU with external Wi-Fi connectivity is an observable and fast-growing trend in automotive. As ever more vehicle functions become enabled by software, OTA updates are becoming vital to the maintenance of connected cars throughout their life cycle. Furthermore, a number of Tier Ones and location intelligence providers are developing new connected services built on crowdsourced sensor data. While some of these data can be transmitted in real-time via cellular networks, the sheer volume of sensor data mandates local storage on the vehicle, before sideloading via Wi-Fi when possible. The crowdsourcing paradigm not only delivers compelling new services, but will also be a vital technology in the creation and maintenance of digital maps.

Therefore, the prevailing automotive megatrends will continue to drive fitment of Wi-Fi to the vehicle TCU. Given that the DSRC radio incorporates a Wi-Fi radio to enable the IEE802.11p protocol, it would be possible to load 802.11a/b/g/n/ac software when the vehicle comes to a halt before resuming 802.11p V2X functionality. A typical automotive-grade Wi-Fi chipset carries an ASP of US$3.

*Figure 4: DSRC Re-use for Alternative Wi-Fi Applications in Automotive* ***(Source: ABI Research)***



There is little evidence of vendors looking to re-use the DSRC radio in this way, with most looking to optimize the 802.11p Wi-Fi radio for the high-speed use case, while fitting a further dedicated Wi-Fi chipset to enable OTA/sensor data crowdsourcing. This can also be attributed to the fact that the OTA and crowdsourcing trends are accelerating to market far faster than DSRC, or V2V more generally. That said, it is technically feasible that OEMs could take advantage of this hardware re-use over a longer horizon.

## SUMMARY AND CONCLUSIONS

*Table 1: Summary of Architecture Differences and Cost Implications C-V2X+LTE and DSRC+LTE* *(Source: ABI Research)*

| Architectural Distinction | Cost Differential |
|---|---|
| LTE ruggedization and automotive qualification | US$5 |
| High-accuracy TCXO | US$8 to US$10 |
| Royalties | US$0.50 to US$1 |
| Additional Wi-Fi radio | US$3 |
| Total | US$16.50 to US$18 |

When taking into account the cost of an extra Wi-Fi radio in C-V2X TCUs, the additional system cost relative to DSRC varies between US$16.50 and US$18. However, because there is almost no traction in the market for re-use of the DSRC radio for alternative Wi-Fi use cases, ABI Research expects that DSRC+LTE architectures will feature a separate Wi-Fi radio costing US$3 in much the same way as C-V2X+LTE architectures will. Therefore, ABI Research estimates that in the initial years of deployment, C-V2X+LTE will carry a system cost between **US$13.50 and US$15 higher** than DSRC+LTE.

DSRC, being the longer established/incumbent technology, has cost advantages typically associated with deployments in the field and a more competitive ecosystem. As C-V2X begins to scale, it can be expected that the cost differential will begin to narrow, and stakeholders in this ecosystem will continue to emphasize the additional use cases that their technology can enable, particularly once 5G supports safe automotive connections over the network. However, with respect to the core, safety-centric V2X use cases, ABI Research expects DSRC+LTE architectures to enable OEMs to deliver this functionality at a lower cost than C-V2X+LTE for the foreseeable future.

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