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BLACKBERRY IVY IN DEPTH

Exploring a Foundational Data Insights Platform for the Software Defined Vehicle

WHITEPAPER

INTRODUCTION

The next phase of automotive evolution is the software-defined vehicle (SDV). By continually improving the vehicle's features and services, the SDV offers a fundamentally better product for the consumer and provides an exceptional platform of innovation for the automaker. However, this new paradigm entails uprooting the entire automotive software lifecycle and realizing it requires a massive investment by OEMs in engineering, tools, infrastructure, and process.

How can an automaker ensure this investment will pay off? By taking advantage of the vast amount of information continually created by their vehicles. Recognizing this, many automakers are preoccupied with the myriad of challenges to obtaining vehicle data with efficiency and at scale: complex hardware/software configurations, connectivity establishment, data privacy and ownership, non-standardized frameworks, and cybersecurity risks.

Yet data by itself is meaningless. What gives data its value are the insights that it provides. Intelligent insights generated from vehicle data can inform automaker product strategy, drive exceptional customer experiences, and build brand loyalty.

These insights can also generate new revenue streams, empowering new business models and opening entire ecosystems of contributors. These important insights are key to driving differentiated value and are a crucial element in making the SDV a success.

At BlackBerry, we recognize that generating vehicle insights is a significant unsolved problem. Therefore, we decided to develop BlackBerry IVY™ in partnership with cloud provider Amazon Web Services (AWS). IVY™ is a fully realized data-insights platform that is uniquely situated at the edge and provides automakers and other third parties with the necessary insights to maximize their ROI and time-to-market. This technical white paper examines the significant problems faced in generating insights from vehicle data, explains how IVY solves these problems, and describes the components of the IVY solution at an architectural level.

THE VALUE OF INSIGHTS

So, what exactly do we mean when we say "insights"? Insights are the result of processing vehicle data to derive meaning that isn't present in raw data. They can be simple numbers such as estimated cargo weight or total passengers, or they can be complex attributes like personal identity or driving-style characteristics. Insights can use rule-based logic or run a machine-learning model within the vehicle – in other words, at the edge of the network. The real-time generation of insights within the vehicle allows them to be integrated into other in-vehicle consumer experiences, allowing the vehicle to continually improve and adapt to meet driver and passenger needs.

Insights are critical to the SDV. They enable the automaker to dynamically expand the vehicle's functionality with new innovative uses of existing vehicle and sensor data. Adding a platform for edge insights allows the automaker to roll out new capabilities after the vehicle has shipped – a core benefit of the SDV.

EXAMPLES OF HOW INSIGHTS CAN PROVIDE BUSINESS VALUE

RAW DATA	GENERATED INSIGHT	CUSTOMER EXPERIENCE
Driver monitoring-system camera feed	Vehicle occupant identification	Enabling specific driver profiles, media playlists, and payment system
Driver monitoring-system camera feed, seat weight sensor	Children in back seat	Automatic locking back doors and enabling explicit media controls
Battery voltage, HVAC settings, ECU messages	Features causing heavy battery load	Providing accurate EV range estimates and guidance to driver for extending range
Wheel tick sensors, lateral acceleration, steering angle, brake temperature	Brake and tire wear	Informing driver about predictive vehicle maintenance and suggested service appointments

Table 1: Examples of how raw data needs to be transformed into insights to deliver excellent customer experiences.

THE CHALLENGES OF INSIGHTS

Getting insights out of vehicle data requires components both within the vehicle and the cloud. At a minimum, extracting vehicle data requires a software module residing within one of the vehicle ECUs (at the edge).

PLATFORM PROLIFERATION

To get insights from vehicle data requires software running in the vehicle. However, for multiple reasons, there are a huge number of distinct vehicle platforms. This platform proliferation is one of the biggest and thorniest challenges in developing a robust insight generation solution. Software developers need consistency and vehicle platforms are anything but. There are multiple levels of this issue:

- **ECU.** The ECU that runs in-vehicle data monitoring and extraction must have sufficient spare processing power and memory as well as access to all the desired vehicle buses.
- **Vehicle models.** Different models have divergent architectures, timelines, features, and underlying capabilities.
- **Trim-lines.** Data attributes, ECU types, and platforms may change between trim lines of the same model.
- **Vehicle model year.** In-vehicle platforms and the cloud software they connect to must be consistently updated or risk platform fragmentation over time.

The difficulty of managing multiple platforms also impacts engineering staff. Building software that addresses every unique platform's requirements demands a snapshot of an entire toolchain. This means managing the compilers, compiler flags, libraries, dependencies, linkers, code signing, testing, and download tools, along with the specific binary and versions of each tool for every distinct vehicle platform. While solutions such as containers can help, they don't erase the massive burden of maintaining all these custom development environments.

Containers also do not remove the exponentially increasing investment in server build time from new targets, whether manually building software or using best practices like a CI/CD workflow.

While OEMs could potentially solve these problems within their own kingdoms, completely standardizing on a single platform across all of an OEM's makes and models would be a costly, long-term project with no guaranteed ROI and a difficult roadmap to success. Analyst firm SBD estimates that developing an edge to cloud computing software platform (like IVY) would cost between $65M and $115M over ten years and that is a small fraction of the overall software investment required. New OEMs may be at an advantage to begin with, but most of them have very few vehicles on the road. They too will eventually suffer issues due to model year changes, internal platform differentiation, and solution portability.

Third-party solution providers have an even bigger problem. Standards and software used between OEMs – for example, the CAN bus or Android Automotive OS (AAOS) – are often customized by each automaker. A third party must deal with the consequences of developing, testing, and managing dozens or hundreds of unique variants across OEMs or alternatively have their products isolated to a small pool of vehicles with highly constrained growth.

CLOUD-EDGE DIVISION

Once the vehicle-side platform scaling issue is solved, another issue for creating insights must be addressed: architecturally splitting which software belongs in the cloud versus within the vehicle. At first glance, the cloud seems like the ideal place to host the bulk of vehicle data collection, processing, and value extraction. This would allow the cloud software to be changed on the fly and for heavy-duty compute machinery to chew through the data with whatever algorithms are needed.

However, the cost challenges within a cloud-centric model are considerable. One severe problem is the economics of data transfer. Forcing the vehicle to send all the necessary data where the decision-making lives — in the cloud — comes with serious cellular costs. While these carrier costs might be offset by new revenue streams, it is a huge gamble for the OEM that a service will have enough uptake and many user-valuable services have no-to-low margins. As a result, the OEM ends up burdening the user with higher additional fees. Further costs incurred by a cloud-centric model are from cloud data storage and processing that can become prohibitive when deployed at scale. While we believe that cloud-based solutions are part of the answer, a cloud-centric model severely impacts profitability; the best architecture skews towards edge processing and storage to maximize benefits and flexibility while minimizing costs.

BEING CAREFUL WITH DATA

There are several OEM sensitivities around vehicle data accessibility that must be managed with any data insight platform.

DATA CONTROL

An OEM may not want to make all signals available to all applications. There can be several reasons for this — the data rate could be too high for the application framework, the data format could change depending on internal states or other non-obvious characteristics, or the data could be highly proprietary. These needs may also change dynamically. For example, the vehicle may need to throttle back data feeds when the ECU is under high load. In any case, what, when, and to whom data is available is a decision best left to the automaker.

DATA SECURITY

OEMs need to restrict the vehicle data to valid uses. This requires cybersecurity measures such as encrypting the data's transmission and storage. It may also require OEM-blessed certificates for certain highly sensitive use cases such as allowing third party access to ECU reprogramming data.

DATA PRIVACY

The increased scrutiny of individual data usage and the patchwork of global data privacy laws and regulations means that automakers must take special care about the vehicle data they share with third parties and external clouds. Processing that data within the vehicle allows them to exert maximum control over the sharing of personal data before it gets released to any external agents.

MOVING INSIGHTS TO THE EDGE

We believe that many of the issues in developing a generic data insight platform are solved by moving the insight generation to the edge. Keeping the data and insight computation in the vehicle has many benefits:

- Preventing huge carrier bills by eliminating the need to send massive amounts of data
- Avoiding excessive cloud storage and cloud processing fees
- Mitigating data privacy and data ownership issues
- Allowing the OEM to be in control of their vehicles' data and accessibility

- Avoiding issues where connectivity is inconsistent or slow
- Providing extremely low latency for high-importance or high-frequency signals

While the BlackBerry IVY platform's model does require more processing power within the vehicle, architectures are already trending toward high-performance computing in the vehicle. The model takes advantage of the ample processing at the edge while minimizing cloud costs, especially considering that the trend of in-vehicle processing is escalating for the software-defined vehicle.

THE CHALLENGES OF EDGE-BASED INSIGHTS

While generating insights at the edge does solve many of the problematic issues that plague a cloud-centric model, it doesn't remove all problems. There are still challenges to be tackled.

- **Specialized developers.** Developing software for the car usually requires embedded automotive knowledge, a relatively narrow skill set with a limited pool of engineers.
- **Heterogeneous data.** The wide variety of vehicle platforms and data sources makes it difficult to acquire clean and consistent data, something that is mandatory for proper training and execution of machine learning (ML) models and data analytics.
- **Limited resources.** Any in-vehicle insight platform must be wary of the constraints of resources like memory and available processing power, and prevent overburdening vehicle CPUs.
- **Using hardware acceleration.** Related to the resource concern, is how to evaluate machine learning models most efficiently. In other words, an insight platform needs to take advantage of hardware acceleration, when possible, despite the diverse nature of possible coprocessors.
- **Maintaining security and safety.** Code developed to generate insights must be able to be centrally managed and securely deployed to the vehicle. Adding this code to the vehicle can never compromise safety of any of the vehicle subsystems.
- **Protecting data.** While the security, ownership, and control of vehicle data is greatly simplified compared to the cloud-based model, it still requires a well-designed data framework to manage access and restrict it as necessary.
- **Sharing insights.** Once insights are generated, an API must be developed that can share insights to other vehicle services – or potentially deliver them to the cloud.

BLACKBERRY IVY SOLUTION

Now that we've stepped through the many difficulties that come from extracting actionable and valuable insights from the vehicle's data, let's look at how BlackBerry IVY addresses these challenges.

WHAT IS IVY?

In short, IVY is a powerful platform for generating data insights. It consists of in-vehicle middleware that is designed to be easily integrated into the OEM's existing vehicle software architecture, a cloud backend and control console, and a set of developer tools. It is designed to solve the challenges of edge-based insights:

- **One platform.** The IVY platform provides a consistent run-time environment for insight generation, and is adapted to each in-vehicle SoC, hardware, operating system, and software stack so that the automaker retains control – not a third party.

- **No specialized developers.** IVY doesn't require special engineers to write insight code. Developers use the tools they're most comfortable with and use IVY tools to wrap their code so it will execute properly in the vehicle run-time environment. IVY provides SDKs and emulation tools that make in-vehicle software development easy.

- **Normalized data.** IVY provides a consistently normalized view of vehicle data regardless of platform or data source, making it possible to execute ML models as well as refine them to correct for model drift.

- **Intelligent resource use.** IVY is aware of in-vehicle resource requirements and can throttle back CPU and memory usage as needed, as well as execute ML algorithms with hardware acceleration when appropriate on supported hardware.

- **Secure and safe deployment.** IVY provides a cloud console for managing the in-vehicle software and uses existing OEM telemetry and OTA resources to safely access the vehicle. Once software is running in the vehicle, it is within a contained environment that protects the remainder of the vehicle systems.

- **OEM-controlled data.** Automakers can completely decide who gets access to their data and when; data is kept safe and private within the vehicle.

- **Insight access.** IVY provides APIs so that insights can be consumed by other vehicle services and applications, and integrated into the OEM's cloud provider of choice.

THE BLACKBERRY IVY ARCHITECTURE

Figure 1 shows the three main parts of IVY: the in-vehicle runtime platform, the IVY cloud back-end, and the development toolkits. Let's examine each of these in detail.

IN-VEHICLE RUNTIME PLATFORM

The proliferation of hardware platforms can easily overwhelm efforts to deploy a data-dependent service at scale. BlackBerry IVY solves this platform issue by creating a runtime environment that remains consistent regardless of the in-vehicle embedded target. The IVY edge runtime allows developers to create software sensors – software modules that run in the vehicle and examine vehicle data, run algorithms, and generate insights.

Because the IVY edge runtime creates a unified execution environment, a software sensor package is created once and can be deployed to all vehicle platforms.

Software sensors are at the core of IVY – they are the units of code running in the IVY runtime (within the vehicle) that process vehicle signals to extract intelligent insights.

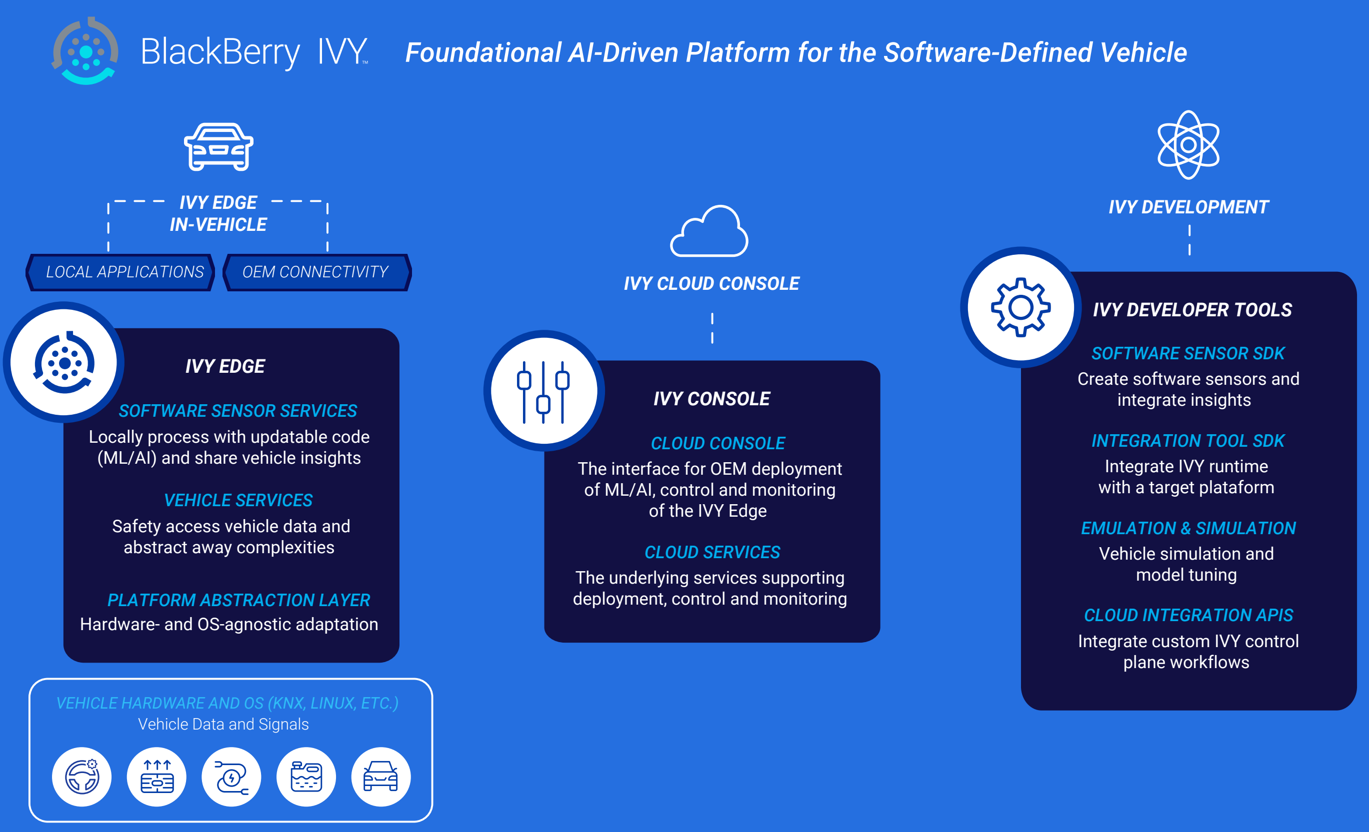

Figure 1. The BlackBerry IVY platform architecture is designed to avoid many challenges in extracting value from vehicle data.

The IVY edge runtime has three main parts:

- **Platform abstraction layer** – this integrates IVY into an OEM's software stack and adapts it to the underlying operating system (OS) and the system-on chip (SoC) hardware
- **Vehicle services** – the connector to the vehicle, providing access to vehicle signals and sensors (CAN, MOST, SOME/IP, video streams, etc), customized by the automaker
- **Software sensor services** – Independent software modules deployed to the vehicle

IVY runtime provides all the necessary tools to control the software sensor lifecycle, deploying, running, stopping, and uninstalling them. These tasks are coordinated intelligently with other vehicle functionality so that software sensors do not overtax the vehicle's capacity.

For real-time response, insights can be delivered within the vehicle to software such as to the digital cockpit or infotainment system. Generated insights can also be used within other software sensors, allowing software sensors to build upon one another. Insights can also be delivered to cloud-based agents within the OEM's IT infrastructure.

CLOUD CONSOLE

IVY has a set of cloud services that manages the in-vehicle software sensors across the fleet and provides access to the generated insights.

- **Cloud console.** IVY provides a cloud console to download, control, and monitor software sensor execution within the vehicle fleet.
- **Cloud services.** These are the underlying services that perform the management and monitoring of software sensors within the vehicle. The OEM's IT infrastructure can call the IVY cloud integration APIs to manage those sensors or gain access to the insights within the vehicle.

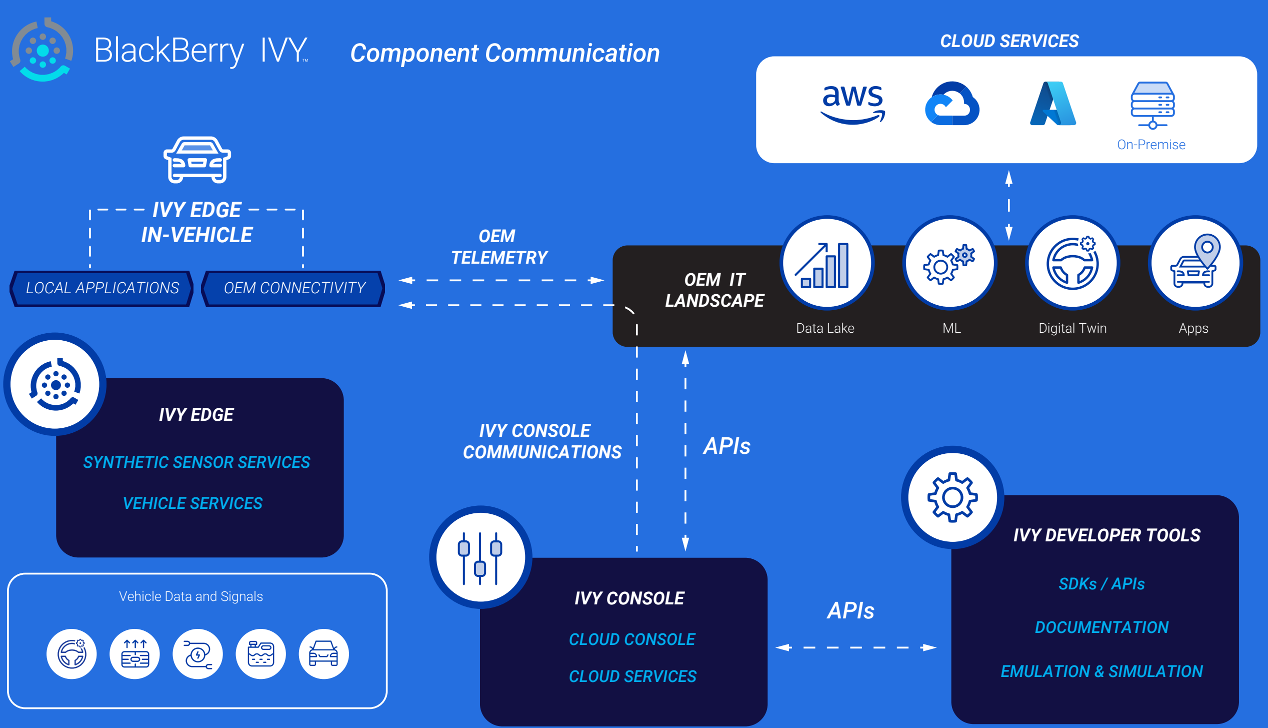

Figure 2. IVY uses the OEM's existing vehicle architecture and IT landscape to extract valuable insights from the edge and deliver them to the cloud.

CASE STUDY: COMPREDICT

COMPREDICT is a company developing software that could replace expensive vehicle sensors. With machine learning techniques, they take data the vehicle already generates, such as engine speed, torque, wheel speed, lateral acceleration, and steering angle, and use this to compute derived values like cargo mass, number of passengers, wheel force, and EV battery health. Their software can be used to implement in-vehicle UX features, predictive maintenance, fleet-operation optimization, and OEM design improvements.

As a startup transitioning to a scaleup, COMPREDICT specializes in algorithms and machine learning, not embedding software in vehicles. They found the process of creating proof-of-concept vehicles extremely laborious due to the sheer complexity of the OEM specifications, the lack of standards, the inconsistency between vehicles, and the specialized tools and specific toolchains required. It took them about a year to get their first in-vehicle ECU running. They knew if they did not reduce this timeline, they could never scale.

BlackBerry IVY was a perfect solution for them. According to Stéphane Foulard, the CEO: "The first time we used IVY, we were able to set everything up from implementation to user interface in just five weeks – an astounding time savings from the 10-12 months it would normally take."

Just as critically, once their IVY port was complete, because IVY data was normalized across all platforms, the same software sensor they developed was now available on all IVY-compatible vehicles. IVY let them focus on their strengths, instead of on the vehicle environment and data transfer issues that previously absorbed most of their development effort, and allowed them to easily scale to meet future needs. COMPREDICT now estimates that if they want to deploy a new algorithm using IVY that it will take at most one week – a remarkable improvement that enables them to successfully scale their business.

DEVELOPMENT

BlackBerry IVY has four main development streams with SDKs, APIs, and tools for extending and adapting the IVY platform and creating software sensors.

- **Software sensor SDK.** This toolkit allows developers to wrap algorithms so they can be deployed to the vehicle as a software sensor. While BlackBerry IVY has special support for machine learning evaluation (such as hardware acceleration for ML model evaluation on supported software), the software sensor code can use whatever technique and tool makes the most sense – like machine learning, rule-based, or analytic methodologies. No special embedded development skills are needed since IVY allows developers and data scientists to use the tools and processes they prefer, such as Python or C++. The software sensor SDK also includes APIs for consuming software sensor insights in C, C++, and in Java, and Kotlin for Android™.
- **Integration tool SDK.** The IVY runtime has a thin abstraction layer to let the OEM customize it for different platforms. This SDK provides automakers with everything needed to adapt IVY for a particular hardware and vehicle platform, including documentation, porting guides, reference code, and examples. IVY is designed for maximum portability, and can run on several operating systems, or even as a module within the QNX® Hypervisor.
- **Emulation and simulation.** Of course, IVY runs in the in-vehicle embedded system, but it also can run in a desktop emulator or in a cloud instance using the AWS Graviton hardware. This allows developers to rapidly test, iterate, and refine their software sensors without requiring vehicle hardware or development targets that are costly and often difficult to obtain.

- **Cloud integration APIs.** Although IVY provides a cloud console UI, OEMs may have existing cloud dashboards. Using the IVY platform's cloud integration APIs, IVY functionality and workflows can be integrated into an existing cloud dashboard or application. The cloud console implementation uses AWS as a reference, although the cloud integration APIs can be called from the OEM's cloud of choice (including AWS, Microsoft® Azure®, Google Cloud™, or even on-premise solutions).

IVY LEADS TO PARTNER ENGAGEMENT

Because IVY uses common tools, APIs, documentation, and workflows, it offers a standardized platform that helps OEMs much more rapidly generate insights from the SDV. This unified platform allows automakers to engage with partners, suppliers, and third-party developers much more easily. A standardized platform is clearly attractive for suppliers too since IVY solves a raft of issues in bringing value into the vehicle. As a result, a number of industry-leading partners, like Amazon Alexa, Bosch, CarIQ, Cerence, COMPREDICT, CerebrumX, Electra Vehicles, HERE, and Pateo, are already part of the IVY ecosystem.

BLACKBERRY IVY IMPACT

The benefit of IVY for third parties is obvious as they would face extreme challenges scaling their business without it. However, the benefits for the OEM are just as significant. IVY provides a ready-made solution to extract and capitalize on vehicle data insights, built with OEM concerns in mind. By leveraging the BlackBerry IVY infrastructure, architecture, technologies, and partners, automakers can nourish a vehicle-data ecosystem that creates financial value, delivers improved user experiences, and continually cultivates new innovations. And instead of handing over control to another party, they remain in full control of the data, its accessibility, and its monetization.

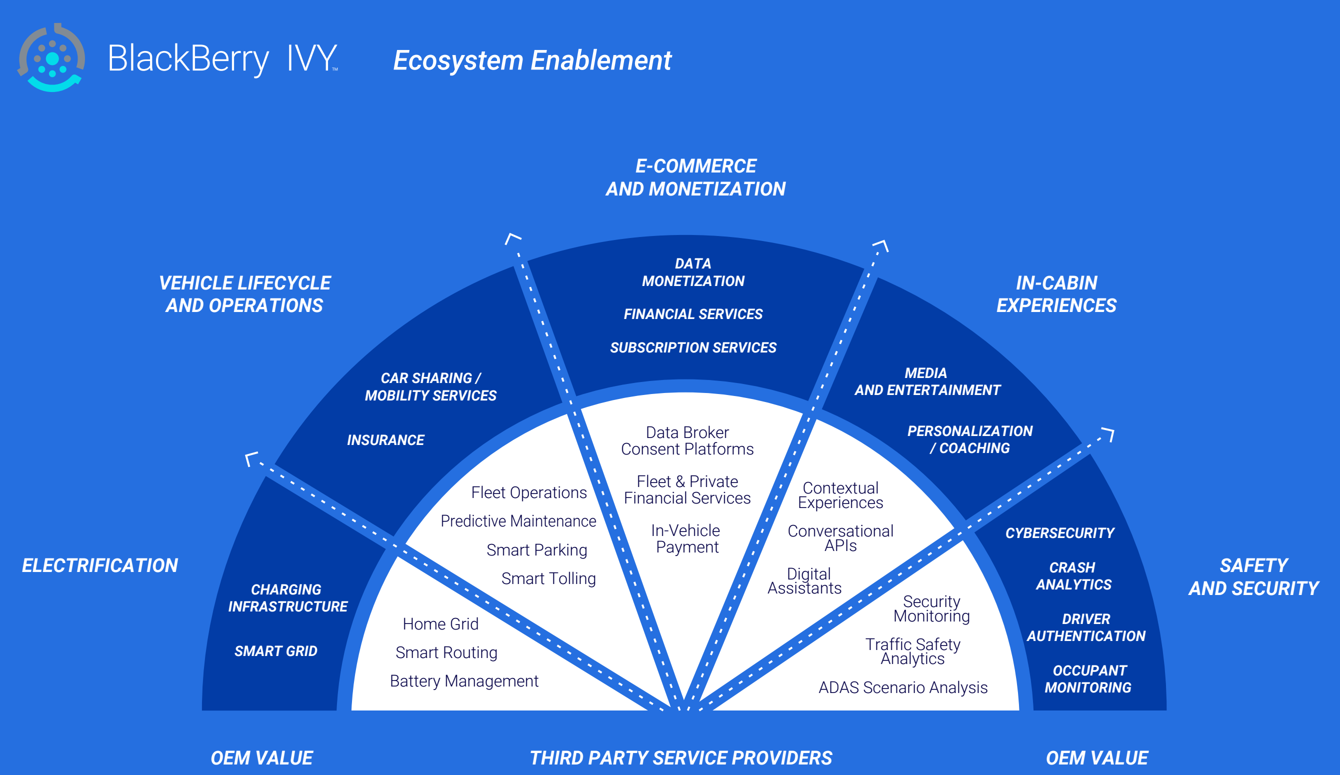

Figure 3. BlackBerry IVY opens up a huge array of services to OEMs, users, and third parties.

TIME-TO-MARKET

Developing an in-house vehicle data solution can take years due to its complexity and cross-departmental coordination. IVY is a platform that exists today and has been designed for OEM adaptation. The time to deployment for the automaker is reduced to vehicle ECU and back-end IT integration using clearly defined SDKs, rather than a scratch-built exercise – a huge speed-up in deploying a functional, tested service.

Time-to-market advantages also extend to any OEM or third-party creating in-vehicle software and services. By letting developers use the development toolchains and workflows that they're already comfortable with, IVY makes development, iteration, and deployment of new vehicle-data-based services lightning fast. Because developers create a single software sensor that works on all vehicles, OEMs can leverage new services as the ecosystem creates them instead of requiring bespoke versions for their fleet.

SCALING AND RISK

An in-house solution requires the entire IT infrastructure to be up and functional before it delivers value. The cost burden is completely front-loaded while the equivalent edge components must be installed across the fleet to try to maximize the investment.

With IVY, the initial investment to deliver on the vehicle-data promise is smaller by orders of magnitude, and an OEM can choose to trial the system with a smaller subset of vehicles to validate business models or potential partnerships before rolling it out to the whole fleet. This makes it easier for the OEM to scale with lower risk. IVY also makes it easy to deploy new services quickly, enabling OEMs to explore new revenue generation models.

ANDROID AND IVY

Does Android negate the need for IVY? Not at all. In fact, IVY is complementary to an Android environment since their primary purpose serves completely different needs: IVY is designed around generating insights from the vehicle's data while Android is built for user-facing infotainment applications. Here are a few comparisons:

- **Middleware.** IVY is a lean software solution that is meant to be integrated into the automaker's software stack that provides mechanisms for the delivery and control of independently developed blocks of code to the vehicle, including execution of machine learning models. Android is an entire software stack by itself.
- **Vehicle data.** Android offers a smaller set of signals heavily focused on cockpit and infotainment features. Based on the COVESA VSS v3 specification, IVY offers an order of magnitude more signals. It can also be deployed to non-cockpit ECUs, and offers fine-grained permission on the signals that can be accessed by software sensors at any time.
- **Platform.** IVY can run on QNX® or Linux® systems, and can be deployed in digital cockpits as well as in smaller ECUs such as vehicle gateways. Android is a whole-stack solution that only runs on infotainment SoCs.

COST SAVINGS

IVY's architectural design uses edge-focused computing, which reduces cloud processing, storage, and communication costs by a massive amount.

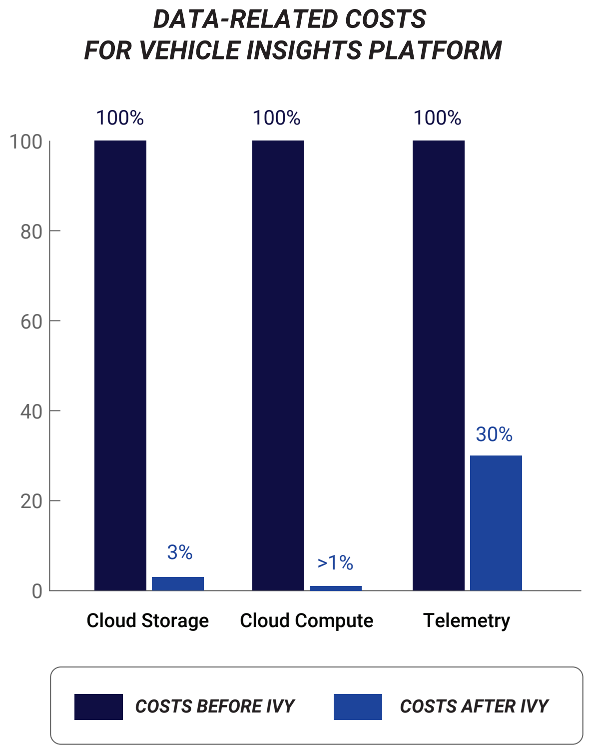

Figure 4. For one example use case, IVY showed potential to remove huge amounts of operational cost from a vehicle data system.

Extracting insights by processing raw-signal data in the vehicle can decimate the fees for cloud computing and cloud storage. As an example, in a scenario similar to COMPREDICT's use case, IVY estimated cloud storage would drop to three percent usage compared to a cloud-based model, while cloud computing costs would become negligible. Similarly, the IVY model greatly reduced telemetry costs: in this same use case, IVY communications fees were estimated at 30 percent that of a cloud-only model.[1]

SUMMARY

The difficulty of extracting value from vehicle data is a challenge that's plagued the industry for years. BlackBerry has brought decades of experience working with automakers and developing in-vehicle software to develop BlackBerry IVY, a solution that solves this problem and helps OEMs deliver quality and innovation on their terms.

[1] This estimate looked at the cloud costs for processing and storage only for vehicle data and generated insights, not other parts of the solution like console use that would remain identical across architectures.

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