Capgemini engineering

IMPROVING MOTORCYCLE SAFETY THROUGH CONNECTIVITY

Introducing a predictable runtime framework for the Connected Motorcycle covering seamless connectivity and security

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Executive summary

The Connected Motorcycle (COMC) is an emerging market that offers greater safety through new telematics applications consistent with the connectivity objectives of the Intelligent Transportation Systems (ITS).[1] There are many advantages of digital connectivity for motorcyclists: access to real-time traffic information, automatic diversion functions to avoid traffic jams, alerts about cheap fueling stations, parking availability, access to highway hazard warnings, and many more.

One forecast projects the global COMC market will reach nearly $900 million by 2027, at a compounded annual growth rate of 47.7% between 2020 to 2027.[2] The strong growth forecast is being driven by rising demand for better motorcycle safety and security, more powerful edge and cloud services, and the emergence of 5G.

The connected motorcycle is an opportunity for manufacturers to provide seamless switching capability for handling new applications such as bike telematics, rider assistance e-calls, and access to 3G, 4G, and 5G cellular services, and Wi-Fi to provide acceptable quality-of-service (QoS) with secure data connectivity. As vehicle-to-everything (V2X) communications mature, a connected motorcycle ecosystem will be able to communicate with infrastructure, cars, trucks, bicycles, other motorcycles, and pedestrians to improve overall safety. (See Figure 1.)

Figure 1: Seamless connectivity for the COMC

Source: Capgemini Engineering

[1.] US Intelligent Transportation System, Joint Program Office, US Department of Transportation

[2.] Report, "Global Connected Motorcycle Market – Industry Trends and Forecast to 2027," Data Bridge Market Research

When the motorcycle transmits data such as telematics over the internet cloud, its prognostics and diagnostics can be hacked, and enormous volumes of data about the motorcycle's performance, rider behavior, and user preferences can be captured. The critical data generated provides greater insights and value for various stakeholders, including the motorcycle manufacturer, Tier-1 suppliers, and mobile network operators.

All the vital data generated from the motorcycle must be communicated seamlessly and securely using different wireless network interfaces. The objective is flawless network connectivity for the motorcyclist to access the critical services from the service provider during their ride. With advancements in vehicle telematics, network connectivity has become a requirement to remotely monitor the motorcycle's performance and provide better service to the end-users.

This whitepaper focuses on the Capgemini Engineering switching mechanism for the COMC initiative, covering QoS-supported seamless connectivity with session persistence based on network performance, cost, user preference, and secure data transmission. Given the dynamics of the network characteristics of cellular and Wi-Fi wireless technologies, the paper addresses the desirable switching outcome for COMC by balancing lower operational costs and communications quality for the selection of wireless networks. Also, the report presents and discusses the COMC test bench and setup for validating the switching of network connectivity for cellular and Wi-Fi networks.

Overview of the Connected Motorcycle (COMC)

From the Internet of Things (IoT) to the Internet of Vehicles (IoV), end-users depend on wireless networks for fast, reliable access to information. Creating an edge gateway on the motorcycle would provide connectivity for the rider to the external world and ensure end-to-end connectivity with a reliable, fast, and trusted network based on the applications needed and user preferences.

For example, an error message would be transmitted to the service provider using wireless communications when a motorcycle has a communications failure. The error message from the motorcycle would be stored in the database and analyzed by an authorized motorcycle service technician. Providing fast repair and maintenance support on the roadside is a challenge that can be managed with network connectivity that regularly monitors the motorcycle data. Different wireless communications support is required for 3G, 4G, 5G, and Wi-Fi to transmit the motorcycle's data and provide quick service by a technician.

At the same time, if the dataset is hacked, it will reveal data about the rider and the motorcycle's performance. Thus, the risk of hacking is not the physical access to the motorcycle but the interception of the data transmitted by the motorcycle's edge gateway that runs motorcycle applications, both OEM-specific applications and third-party software. Hacking motorcycle data could become a major risk for COMC during a live connection or when switching between different networks (e.g., before a successful handover). In addition, motorcycle data hacking can lead to software design failures. It is easy for an attacker to alter motorcycle data software by creating malicious settings. To address this challenge, the wireless-enabled network on the motorcycle must be protected and patched to eliminate exposure to malicious actors.

The characteristics of a wireless network differ between cellular network operators. Each operator offers varying speed, security, and reliability levels, making connectivity more difficult for the mobile network operator (MNO) to provide better QoS to meet the user's expectations. In addition, the critical problem for the transmission of telematics and safety data latency can result in poor performance. A major connectivity issue for a motorcycle network that communicates over cellular networks would be hard to predict when the cellular network connectivity will drop off the network, go offline without warning, or know when the motorcycle will be reconnected to the cellular network. Moreover, COMC applications that run on the motorcycle require reliable connectivity, so the rider always has access to the information.

Here is a list of the key features that ensure seamless switching for the COMC:

- Automatically identifying, selecting, and switching to the best available wireless network based on the preferences and policies defined by the end-user continuous handover between different networks (See Figures 2 and 3.)

- Providing secure connectivity during switching between networks and maintaining session continuity for the motorcycle
- Providing QoS connectivity for different wireless networks by monitoring continuously. If the performance of a connected wireless network does not meet the defined threshold value, the network needs to switch to ensure seamless connectivity with other preferred networks
- Offering user-specified preferences, specifically for applications like telematics and safety
- Ensuring seamless switching with session persistence for critical motorcycle applications
- Delivering seamless connectivity with less data and packet loss over the entire motorcycle mobility landscape

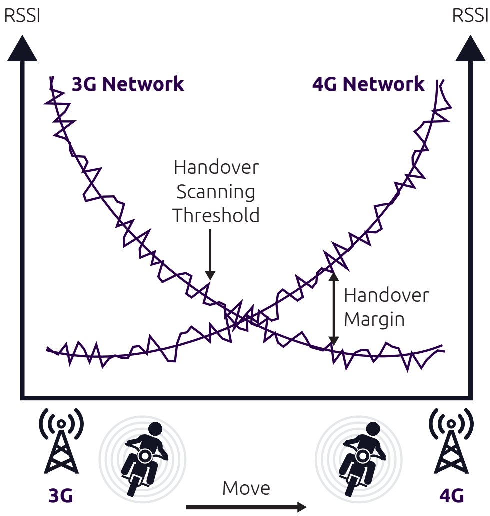

Figure 2. The handover threshold limit
Source: Capgemini Engineering

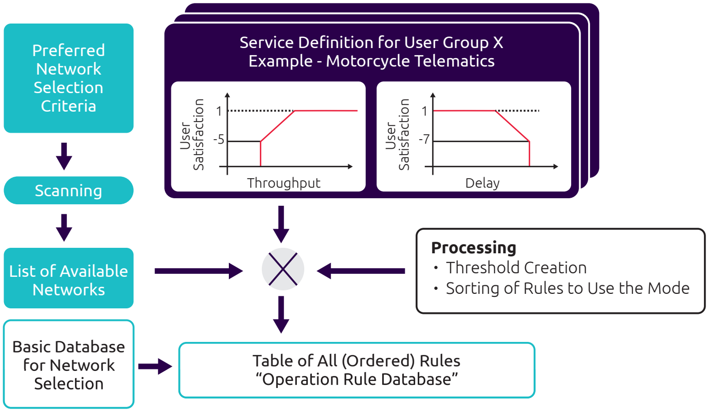

Figure 3. The COMC make-before-break concept

Source: Capgemini Engineering

The COMC applications listed below require continuous and robust network connectivity with a secure way to transmit data that provides a better experience for the rider.

1. Motorcycle maintenance
2. Usage-based insurance
3. Motorcycle safety
4. Motorcycle security
5. Concierge services
6. Healthcare (both motorcycle and rider)
7. Home connectivity (a nice-to-have feature)
8. Voice-based controls

1. **Motorcycle maintenance**: Remote diagnostics, maintenance alerts, minimize operational cost with regular service; monitoring the motorcycle's data using the OEM's diagnostics center. (See Figure 4.)

2. **Usage-based insurance:** There are several ways to purchase motorcycle insurance; for example, pay-as-you-drive (PAYD) and pay-how-you-drive (PHYD), based on rider behavior. The insurance company monitors the motorcycle data and will adjust the premiums based on riding behavior history.

3. **Motorcycle safety:** This includes providing information to the rider about accidents and other incidents on the road to avoid collisions. It also provides emergency call services and roadside assistance in case of breakdowns. For example, if an accident happens, the safety sensors send a message to the bike head unit, that acts as the edge gateway, which initiates an e-call to four entities simultaneously: the closest hospital, the local police station, the rider's home, and the rider's closest family member. (See Figure 5.)

Figure 4: Motorcycle telematics monitoring features

Source: Capgemini Engineering

Figure 5: The e-call feature
Source: Capgemini Engineering

4. Motorcycle security: Managing the motorcycle engine remotely from a smartphone triggers a security alert and initiates tracking. (See Figure 6.) Robust, secure connectivity is essential for the bike security feature.

Figure 6: Remote vehicle management by COMC
Source: Capgemini Engineering

5. Concierge services: The suite includes location tracking, traffic, parking, weather, and fuel price information, travel maps, location sharing, last-mile guidance, off-board navigation, and a motorcycle finder app. (See Figure 7.)

Figure 7: Navigation and location tracking

Source: Capgemini Engineering

6. Rider Healthcare: This feature includes data transmission and monitoring rider health data during a ride. (See Figure 8.) Service is provided by placing bio-medical sensors (e.g., heart rate, blood pressure monitors) in the rider's jacket or on their body that communicate to the bike head unit. In the case of an accident, the head unit transmits the rider's data to the hospital for the staff to monitor their health. Connectivity is paramount in this application.

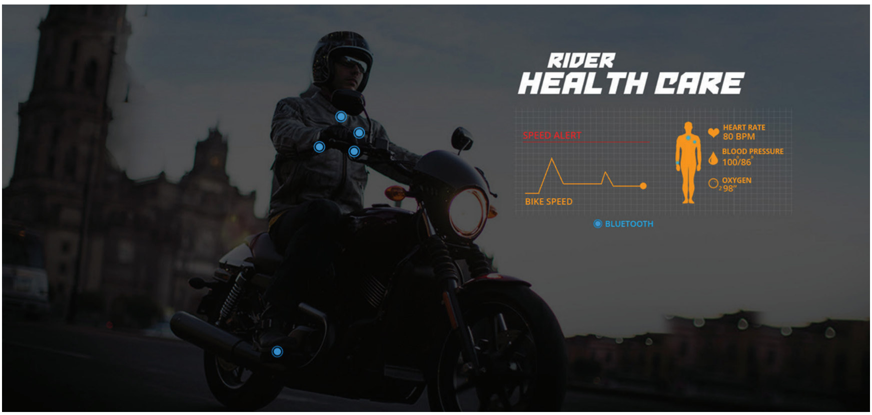

Figure 8: Monitoring the rider's health

Source: Capgemini Engineering

7. Home Connectivity: The ability to link the motorcycle to the home network enables seamless connection for automatic control of home appliances from the motorcycle's network. (See Figure 9.)

Figure 9: Extended connectivity with the rider's home network

Source: Capgemini Engineering

8. Voice-based control: The ability to link the motorcycle embedded platform with Amazon Alexa, Google Home, or other voice-based communications services, enabling seamless connection for the rider to access data during runtime. (See Figure 10.)

Figure 10: Voice-based command

Source: Capgemini Engineering

As the motorcycle becomes more dependent on the network's elements, the consequences of network failures will increase. Concepts like seamless connectivity will fundamentally change the way riders use their motorcycles. A seamless handoff with session persistence for COMC with end-to-end security addresses these issues. Services include QoS-based wireless network selection and decision processes for apps like telematics and safety applications. These apps ensure secure data transmission when switching between wireless networks. A seamless handover framework for COMC with QoS policies can be incorporated to select the best wireless network (e.g., 3G, 4G, 5G, and Wi-Fi), with the riders' preference for data traffic congestion and network bandwidth availability for QoS being essential for their applications.

The COMC industry landscape

From the Internet of Things (IoT) to the The objective of this approach for the COMC is to provide a seamless transition between any IP-based network. Here are the requirements for realizing the seamless handover decision criteria and end-to-end secure data transmission:

- Automatic detection and connection to available cellular and Wi-Fi networks
- Data and session continuity between IP-based networks for critical applications such as e-call, motorcycle telematics, and safety applications such as vehicle-to-infrastructure (V2I)
- Decisions based on QoS perform seamless handover by measuring and monitoring the active (current) and next-available (new) network conditions
- Maintain session persistence during and after handover
- Selection of interface based on user preferences, application requirements, and information about the wireless network such as:
  - Collect signal strength, like RSSI, from PHY layers (e.g., cellular and Wi-Fi) and QoS parameters like delay, jitter, throughput, and packet loss that perform various activities needed for selecting wireless networks
- Continuous monitoring and comparison of QoS parameters with the defined and actual parameters for specific services such as motorcycle telematics, location-based services, e-call, etc.
  - Impact of QoS parameters like delay, jitter, throughput, and packet loss for real-time traffic flow
  - Analysis of QoS measurement mechanism to monitor the status of the QoS parameters during the actual data flow
  - Compare the defined QoS parameters with the actual QoS based on the type of service
  - Negotiate network resources for better QoS and further improvements in case of quality degradation
- Balance the data traffic over available interfaces that are transparent to the user as seamlessly as possible
- Use the priority network (e.g., 3G) for certain services. Use an alternate network for safety applications such as motorcycle surveillance over a Wi-Fi network during park mode for a better data rate and higher video quality based on available signal strength.
- Consolidate information from various interfaces of OSI layers and generate triggers for making handover decisions
- Switch off completely the old network once the signal strength of the new network becomes better than the old network
- Monitor and maintain the requirements defined to meet certain QoS for critical safety applications enabled in the motorcycle head unit and gateway as and when the access network changes

- User preferences: Budget the cost-per-user for using wireless networks
- Latency: Measure the end-to-end latency of the handover
- Preferred network user choice: For Wi-Fi-only connectivity, stay connected based on user preferences and cost. For 3G- and 4G-only connectivity, always connect to 3G or 4G regardless of available Wi-Fi presence
- Security: Take care of critical data when switching between different networks for different motorcycle applications

Based on the requirements and objectives identified above, the vehicle data security and connectivity (VDSC) framework ensures seamless switching for data transfer. (See Figure 11.) At the same time, the COMC interfaces with different wireless and cellular networks. The VDSC framework is based on a motorcycle-initiated, network-controlled concept, where the VDSC framework on the motorcycle side interfaces with various layers of the OSI model at the embedded-system level for measurement of parameters like RSSI and QoS parameters, such as throughput, packet loss, jitter, and delay for different network conditions.

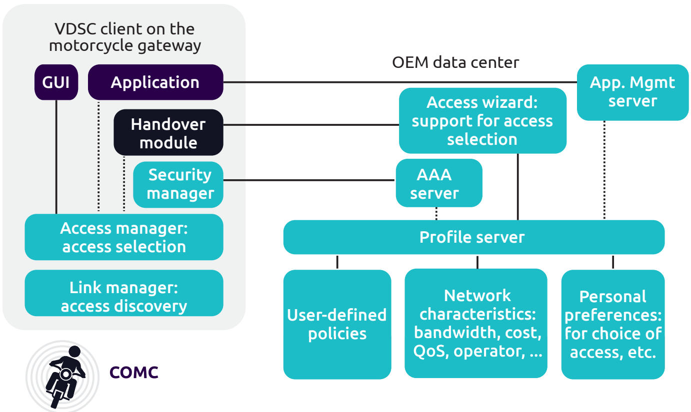

Figure 11: The COMC vehicle data security and connectivity framework
Source: Capgemini Engineering

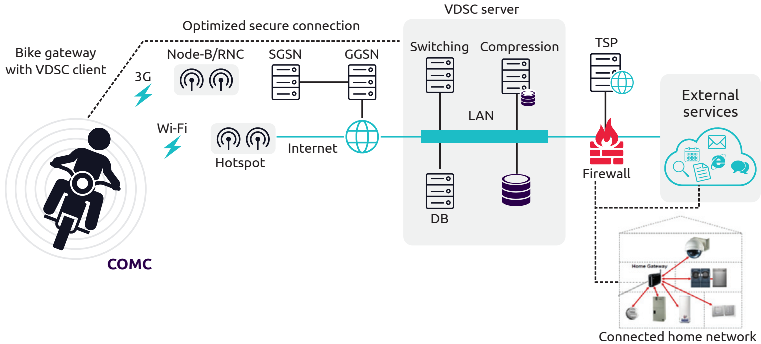

Figure 12: The COMC ecosystem with support of seamless connectivity
Source: Capgemini Engineering

Figure 12 provides an end-to-end COMC ecosystem in a typical real-time scenario. The motorcycle connects over cellular or Wi-Fi to OEM data-center services over the MNO. OEMs and operators can create a new business model for riders who need access to different radio-access networks in the connected motorcycle ecosystem to handle multiple applications for themselves and a passenger. (See Figure 13.) Using "virtual" MNOs, they can ensure they always have the best secure wireless network connectivity for their motorcycle customers.

The Internet of Vehicles (IoV) – specifically in the context of connectivity and security – has proposed a VDSC middleware framework with robust network connectivity that is needed to provide a better user experience. The VDSC enables smooth end-to-end data connectivity across different wireless networks during network switching/failure, ensures data security at any single point in the network, and further accelerates the speed by compressing the data.

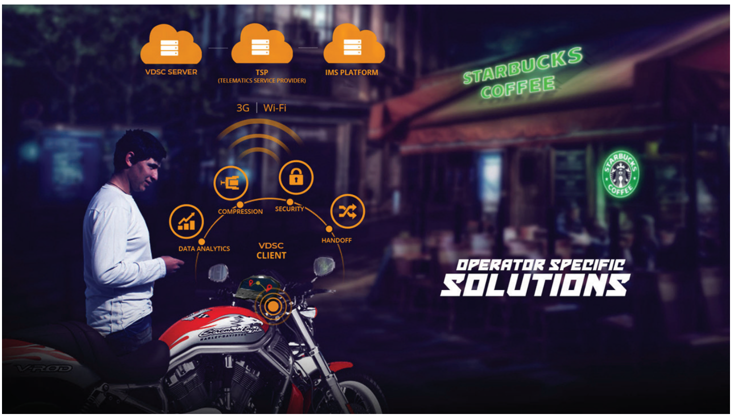

Figure 13: COMC ecosystem with the support of seamless connectivity
Source: Capgemini Engineering

In the context of IoV, which requires speed, trust, and reliability, the VDSC framework offers speed, switching, and security in a single middleware framework that provides high performance, resiliency, and user experience. The VDSC measures the signal quality of available wireless interfaces, compares with the user policy defined based on the data collected over each wireless network and takes the necessary action. Regarding the communication with different networks, the VDSC works in dynamic selection mode with supported functions such as seamless switching with session persistence, encryption, telematics data compression, and authentication while taking care of QoS. Furthermore, the VDSC manages the connectivity of the data traffic from the motorcycle to the OEM service provider network (i.e., the northbound interface). It also manages passenger devices, like smartphones using the motorcycle gateway, to handle voice calls and streaming audio.

The VDSC client software framework runs on motorcycles. (See Figure 14.) It enables dynamic strategy selection of system discovery, handover decision/execution, and the reasons for a network change. Motorcycles might vary based on the following parameters:

- QoS
- Security
- Service
- Reliability

Here are the critical components of the VDSC client framework on the motorcycle gateway:

- Access discovery: VDSC client software uses events that span all layers for discovering the network
- Access selection: Provides seamless connectivity across the underlying wireless network interfaces
- User preference: Network switching based on QoS and cost preference defined for various applications
- Network selector: Takes the QoS requirements configured for the motorcycle application and compares them with the current status of available wireless networks
- Application/configuration interface module: Provides APIs that cover the details, such as user preferences based on QoS demands and limitations. The data is fed into the network selector module to evaluate and decide on the handover process

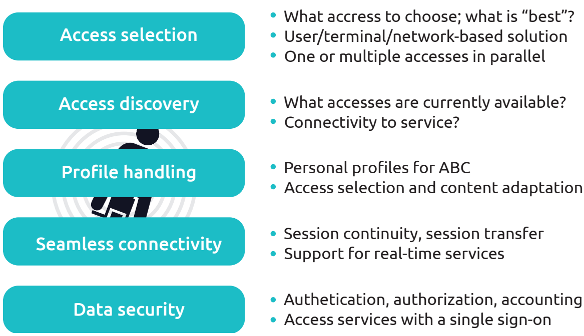

Figure 14: VDSC software services for seamless connectivity with security

Source: Capgemini Engineering

How the VDSC handover works

Once the wireless network has been detected and is available, the VDSC client software processes the configuration details and profile that has been set up for each motorcycle. The VDSC client loaded on the motorcycle head unit scans and searches for available wireless networks from different service providers. This process is the basis for the selection criteria and eliminates networks that are no longer required for connectivity. The VDSC correlates the list of available networks with the user-defined policies describing the required QoS. The expected result is an available network mapped to the desired QoS with service-specific parameters like delay, jitter, bandwidth, throughput, packet loss, etc.

The network scanning process determines the networks covering cellular and Wi-Fi, where the key parameters are the RSSI and QoS parameters like packet delay, loss, and error rate. If the measured parameters at each wireless network are sufficient, then the network selection is rated up and is usable. If the measured parameters are insufficient, the network selection is rated down and cannot be used. Besides the up and down states, intermediate logic can be applied between two states: network up and network down. (See Figure 15.)

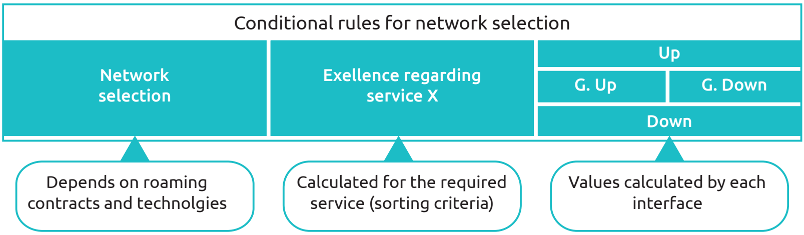

Figure 15: Network scanning logic
Source: IEEE

The up and down states have been chosen for network handover between different wireless interfaces based on the comparison between the currently used rule and the next preferred network based on user preferences configured by the service provider's network. Connectivity with the existing network gets switched to the new preferred network as soon as the state changes to up, and the existing connected network changes its state to network down. The preferred network is triggered to initiate a new connection, where the secured tunnel is maintained with the new network as soon as the network initialization is complete. The seamless handover algorithm ensures that the end-to-end tunnel between the motorcycle and the operator network is routed through the best wireless communication network to maintain session continuity.

The VDSC framework also specifies a policy describing the required service and the specific QoS parameter for each motorcycle application enabled in the head unit platform. The prescribed QoS parameters for the motorcycle telematics are essential for the OEM to provide service to the end-user by monitoring the motorcycle's performance remotely. Motorcycle telematics requires a larger bandwidth for transmitting the relevant CAN/OBD-II data to the OEM service center. It can tolerate only a maximum packet loss and packet delay to provide better service to the user. The VDSC supports automated reconnect in case of network instability or interruption. Reconnect substitutes expensive bandwidth with cheap bandwidth. For example, costly cellular bandwidth is substituted by switching to Wi-Fi in park mode, which reduces data traffic costs and substantially improves the end-user experience.

The VDSC client algorithms are designed and created to identify and select the wireless networks. They are handled by the VDSC client framework based on the "make before break" concept. The VDSC server can be hosted by any cloud platform provider, OEM data center, or service provider. The seamless connectivity can be validated and benchmarked between 3G, 4G, 5G, and Wi-Fi networks. The sample dashboard design of the VDSC server hosted on the cloud (see Figure 16) provides a consolidated view for each motorcycle connected to the VDSC server for the following aspects:

1. Rider behavior pattern
2. Motorcycle health data
3. Alerts
4. Service scheduling based on critical alerts
5. Warnings
6. Geofencing
7. Pay-as-you-drive chart

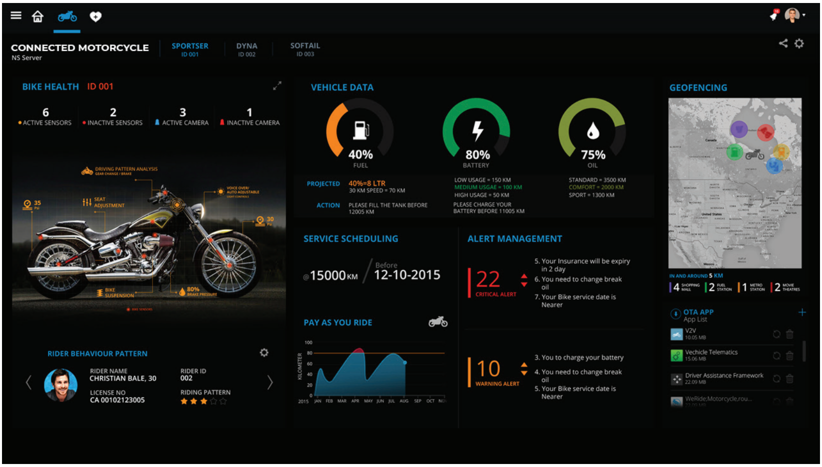

Figure 16: COMC dashboard design for the VDSC server

Source: Capgemini Engineering

3GPP standard evolution towards 5G

The 3GPP Release 16 has specified a 5G core function called access traffic steering, switching, and splitting (ATSSS) that manages the convergence between 3GPP networks, including 5G unlicensed 3GPP networks such as Wi-Fi, which turns heterogeneous networks into a single converged network.[3] (See Figure 17.)

ATSSS delivers an improved user experience for the seamless handover use case. In support of Wi-Fi offload, the focus will be on steering and switching. In some situations, neither cellular networks nor Wi-Fi can deliver stable connectivity. The splitting feature can improve the reliability of the connection by combining available wireless access.

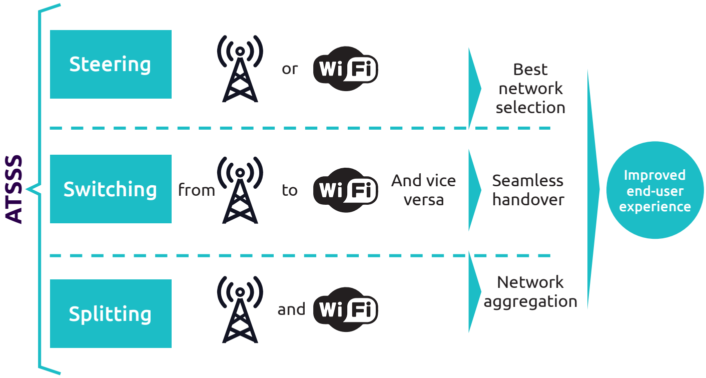

Figure 17: The 5G ATSSS
Source: 3GPP

Conclusion

The connected motorcycle market is growing rapidly and has the potential to significantly boost revenue for OEMs, Tier-1 suppliers, and service providers in the next few years. This white paper has addressed the challenges of providing seamless switching over different wireless networks, so the motorcycle can always be accessed seamlessly and securely using cellular or Wi-Fi networks for various critical features. (See Figure 18.)

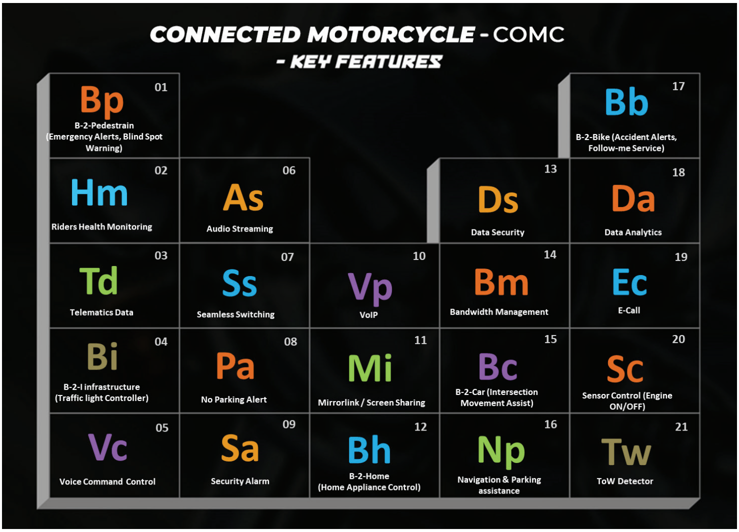

Figure 18: Twenty-one features of COMC

Source: Capgemini Engineering

In critical situations, such as a breakdown, the rider needs to contact roadside assistance. The solution is an "always-on, best-connected" network approach with end-to-end security. The rider can digitally communicate all the required telematics data to a technician who identifies the problem quickly, provides the service, and gets the rider back on the road as quickly as possible.

The vehicle data security and connectivity (VDSC) framework described in this white paper addresses the seamless connectivity over cellular and Wi-Fi networks. With the support of a seamless switching feature supported by VDSC for the connected motorcycle, riders can obtain fast and stable access to the internet and the service provider via different wireless networks: 3G, 4G, 5G, or Wi-Fi. End-to-end secure connectivity and rapid response are critical for accidents and breakdowns.

With a seamless switching feature, the motorcycle has access to a real-time network. The VDSC can generate substantial savings from motorcycle data traffic costs with the smart selection of wireless networks at runtime based on defined QoS and user preferences for specific applications. VDSC provides a secure, seamless, end-to-end connectivity experience with minimal delays.

The rider can substitute expensive or slow bandwidth with cheap, fast bandwidth. For example, an overloaded 3G or 4G network connection at a specific location can be replaced with low-cost wireless hotspots while the motorcycle is in park mode.

The Connected Motorcycle created by Capgemini Engineering is a Honda CBR model. (See Figure 19). It includes a number of components that measure and monitor telematics data and manage connectivity with different wireless networks.

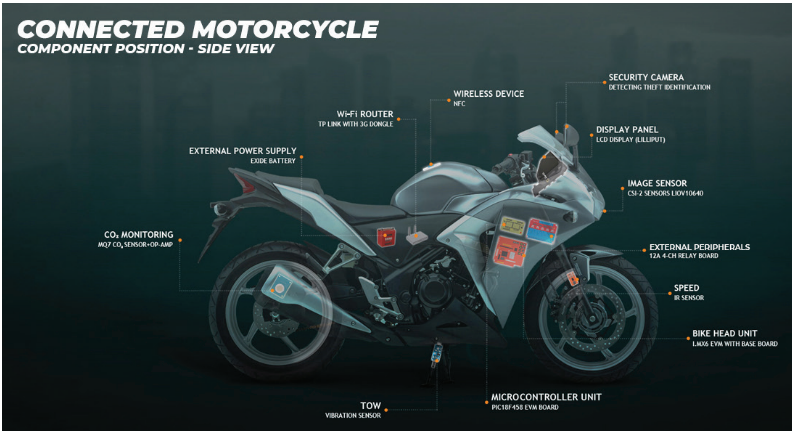

Figure 19: The primary components in the Capgemini Engineering concept Connected Motorcycle

Source: Capgemini Engineering

Capgemini Engineering has validated the VDSC framework on an embedded platform. It is integrated into the motorcycle and provides a seamless real-time mobility handover experience. The timely detection of different wireless networks and intelligent selection of the target network is determined by the QoS requirements, user profile, and application preferences. The system provides a secure, seamless, end-to-end connectivity experience with minimal potential delays. (See Figure 20.) The VDSC connectivity platform directly addresses the most fundamental connectivity challenges in the motorcycling world. The VDSC connectivity framework addresses the fundamental connectivity challenges for the connected motorcycle world. In addition, the VDSC provides an opportunity for service providers to meet end-user requirements and enhance network scalability in an open, competitive marketplace.

Figure 20: A Honda CBR motorcycle with hardware and software upgrades that realize the vision of a connected motorcycle

Source: Capgemini Engineering

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Vijay plays a strategic leadership role building connected IoT solutions in a number of market segments including consumer and industrial IoT. He has over 25 years of experience and has published 19 research papers, including IEEE award-winning articles. He is currently pursuing a Ph.D. at the Crescent Institute of Science and Technology, India.

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