WHITE PAPER

Future-proofing EV charging solutions with wireless connectivity

Abstract

The EV charging market is booming as a growing number of individuals and businesses are opting for electric vehicles (EVs) for their reduced environmental impact, low operation and maintenance costs, and, crucially, monetary and non-monetary subsidies.
This white paper provides an overview of the wireless connectivity technologies that can be used to enable and control the EV charging process, covering front-end communication between the EV charging station and the vehicle itself as well as back-end communication between the EV charging station and the cloud, and offers recommendations on their implementation into successful solutions.

White paper: Future-proofing EV charging solutions with wireless connectivity
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EV charging market landscape

Around the world, the electrification of road vehicles is on the rise. Driven by their reduced environmental impact, low operation and maintenance costs, and, crucially, government monetary and non-monetary subsidies, a growing number of individuals and businesses are opting for electric vehicles (EVs) over conventional ones. By 2030, there will be around 138 million EVs on our streets, and roughly every fourth car sold will plug in to a socket to recharge, according to projections by ABI Research.

The autonomy, range, and ease of refueling of conventional vehicles have set a high bar for EVs. Meeting these expectations will require expanding the network of EV charging stations, speeding up charging, and improving the user experience, for instance, by making it easy to find free charging stations, simplifying billing, and offering a variety of other value-added services. In each of these, wireless connectivity is key.

As a result, public EV charging stations have an anticipated CAGR of 29.4% from 2020 to 2030, following projections by ABI Research. While Western Europe is leading the market in 2020, growth will be fastest in the Asian Pacific market, with close to 9.5 million public charging points projected by 2030. Meanwhile, the EU estimates that it will need around 3 million public EV charging stations on its territory by 2030, up from around 200,000 installed at the end of 2020. [1]

The evolving role of EVs in the power grid

As the number of EVs on our roads grows, their utility will evolve to offer more than just transportation. Taken together, the high-capacity batteries of a city's EV fleet make up a considerable – and decentralized – power reservoir.[2] Eventually, EVs will become an integral component of local energy management systems, storing energy when it is produced in excess, and supplying it to buildings and homes to cover demand peaks. Here, too, reliable and secure connectivity, from the vehicle to the power utility's cloud-based energy management system, will be vital to leverage the full potential EVs hold today and in the future.

In this white paper, we provide an overview of the wireless connectivity technologies that can be used to enable and control the EV charging process, covering front-end communication between the EV charging station and the vehicle itself, as well as back-end communication between the EV charging station and the cloud, and offer recommendations on their implementation into successful solutions.

[1]) https://www.euractiv.com/section/electric-cars/news/massive-rise-in-ev-charging-points-needed-to-reach-eu-climate-goals-new-research-finds/
[2]) https://www.virta.global/vehicle-to-grid-v2g

Technologies and standards in EV charging

EV charging classification

Today, EV charging is almost entirely wired, with two dominant technologies. **AC charging**, available in fast and slow variants, lets users simply plug into an available power socket and is the dominant solution. In this case, the charger sits in the vehicle, shifting the cost to the vehicle rather than to the charging station. Because fast AC charging requires 32 ampere current, which is not commonly available in homes, it is predominently used by commercial charging points.

The trend, however, is towards faster **DC charging,** which, based on data by ABI Research, should make up just over 68% of public charging stations by 2030. Faster charging translates directly into a time gain for drivers and, by making it easier for them to top up their cars' batteries during a trip, increases the range of their vehicles.

Now, **wireless charging** (or inductive charging) promises to further increase the convenience of EV charging. In addition to shortening setup time (drivers simply have to park over the wireless charger), they do away with the need for charging cables, increase safety, and simplify maintenance, as the magnetic field transporting the energy is not affected by dirt or water. According to manufacturers, transfer efficiencies will be on par with current wired charging capabilities. According to Allied Market Research, the wireless charging for EV market is projected to hit US$ 210.1 million by 2030.[3]

EV charging station deployments

Cars spent most hours of the day parked at home and at the workplace. This is where the majority of battery charging demand needs to be met. The remainder of charging is done in publicly accessible locations, such as at service stations, shopping centers, car parks, and other public spaces. As a result, homes and the workplace will be the key locations requiring charging management to ensure successful integration of EV batteries into the electricity grid.

Today, most EV charging stations are operated manually, in that the driver connects the power cable from the charging pole to the vehicle by hand. There is also a push towards a more seamless charging process at wired charging stations: using an automated connection device (ACD), such as a robot arm or pantograph that automatically connects the car with the charging infrastructure. By increasing user comfort and convenience, and making the charging process hassle-free, the user experience offered by wired charging poles will approach that of wireless charging stations.

[3]) https://www.globenewswire.com/news-release/2020/10/28/2115691/0/en/Wireless-Charging-for-EV-Market-to-Hit-210-1-Million-by-2030-Allied-Market-Research.html

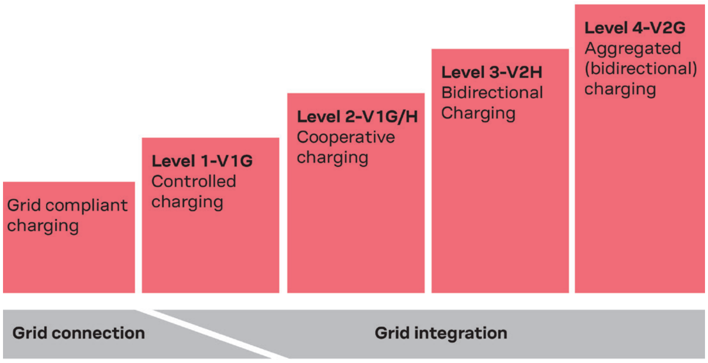
Grid integration of EV charging

CharIn, an industry alliance promoting a combined charging system that covers slow and fast AC and DC charging, has laid out five levels of grid integration.

As illustrated in the figure to the right, the trend is for today's EVs, which simply draw electricity from the grid in compliance with local requirements and regulations, to take on increasingly sophisticated roles as active elements of the power grid.

In **Level 1**, service providers will be able to influence charging power and time to optimize grid performance at a system level. **Level 2** takes this one step further, allowing the EV and the charging station to determine a charging profile that meets monetary and grid constraints. Finally, **Levels 3 and 4**, defined in the ISO 15118 standard, allow for bidirectional energy transfer, with the EV becoming an integrated part of the building energy management system and the grid.[4]

Specifically, ISO 15118 ensures the exchange of information between the EV and the charging station that is required to match supply and demand on the power grid, which is becoming



The four levels of grid integration defined in ISO 15118.

increasingly challenging with the rise of renewable – and intermittent – power sources. Ultimately, EVs could be used to store energy when it is produced in excess of demand and feed it back into the grid to flatten peaks in consumption. The transfer would have to be intelligently controlled to ensure that the EVs are always charged over a certain threshold, taking into account planned and scheduled EV trips, as well as a diversity of power sources, such as domestic solar and the grid, all according to the user's preference.

The essential role of open standards

A prerequisite for the EV charging process to become more integrated is increased communication flow across a variety of entities. This includes **back-end communication** from the charging pole to third-party cloud services, relaying data related to the charging process status, battery levels, and the next planned trip. **Front-end communication**, which flows between the charging station and the EV, is used to exchange vehicle data and monitor and control the charging process. In both cases, open standards for communication are essential to ensure interoperability between competing and complementary services.

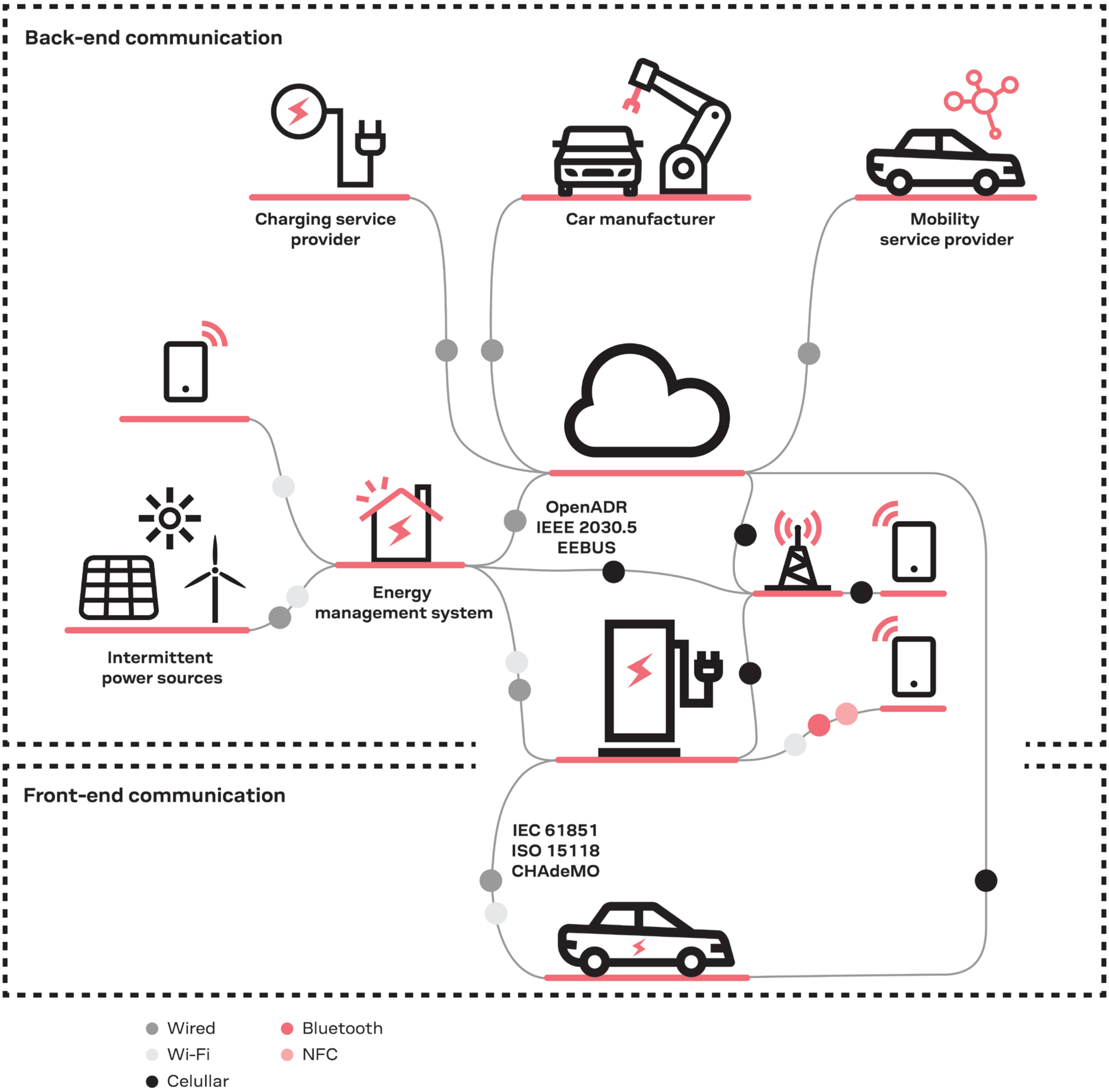
For charging pole installations in homes, residential buildings, and commercial buildings, the communication flow could pass through a local energy management system (EMS), which optimizes the performance of resources within the same ecosystem, such as heat pumps, solar energy systems, and other significant loads. In the case of public charging infrastructure, e.g. on-street chargers, the communication link directly connects third-party operators and charging poles.

There are several open and proprietary protocols used for back-end communication including IEC 63110, IEEE 2030.5, EEBUS, OpenADR, and OCPP. The main alternatives for front-end communication are CHAdeMO (IEC 61851-24) and ISO 11518. A research paper by Myriam Neaimeh and Peter Bach Andersen offers a good description and analysis of the various communication protocols used.[5]

4) https://www.charin.global/media/pages/technology/knowledge-base/60d37b89e2-1615552583/charin_levels__grid_integration_v5.2.pdf
5) https://www.researchgate.net/publication/339153784_Mind_the_gap-_open_communication_protocols_for_vehicle_grid_integration

Wireless communication in EV charging

Going forward, wireless technologies will be increasingly relied upon across the entire EV charging ecosystem, adding new use cases and enabling new business models in addition to simply charging the vehicle. The figure below illustrates the various communication channels that EV charging solutions rely on. When applicable, the appropriate wireless technologies are represented, as are the standards that the communications have to comply with.



Front-end and back-end communication channels commonly used by EV charging stations.

Front-end communication

We define front-end communication to comprise all wired and wireless communication between the wireless charging station and the vehicle. Front-end communication includes monitoring and controlling the EV charging process and exchanging information.

Back-end communication

Back-end communication covers data transfer between the wireless charging station and the home/building energy management system, with Wi-Fi the most commonly used wireless communication technology. Back-end communication to third party cloud-based services can use Wi-Fi or cellular communication. A common use case is for users to monitor the ongoing charging process on their cellphones (via the cloud).

Configuration

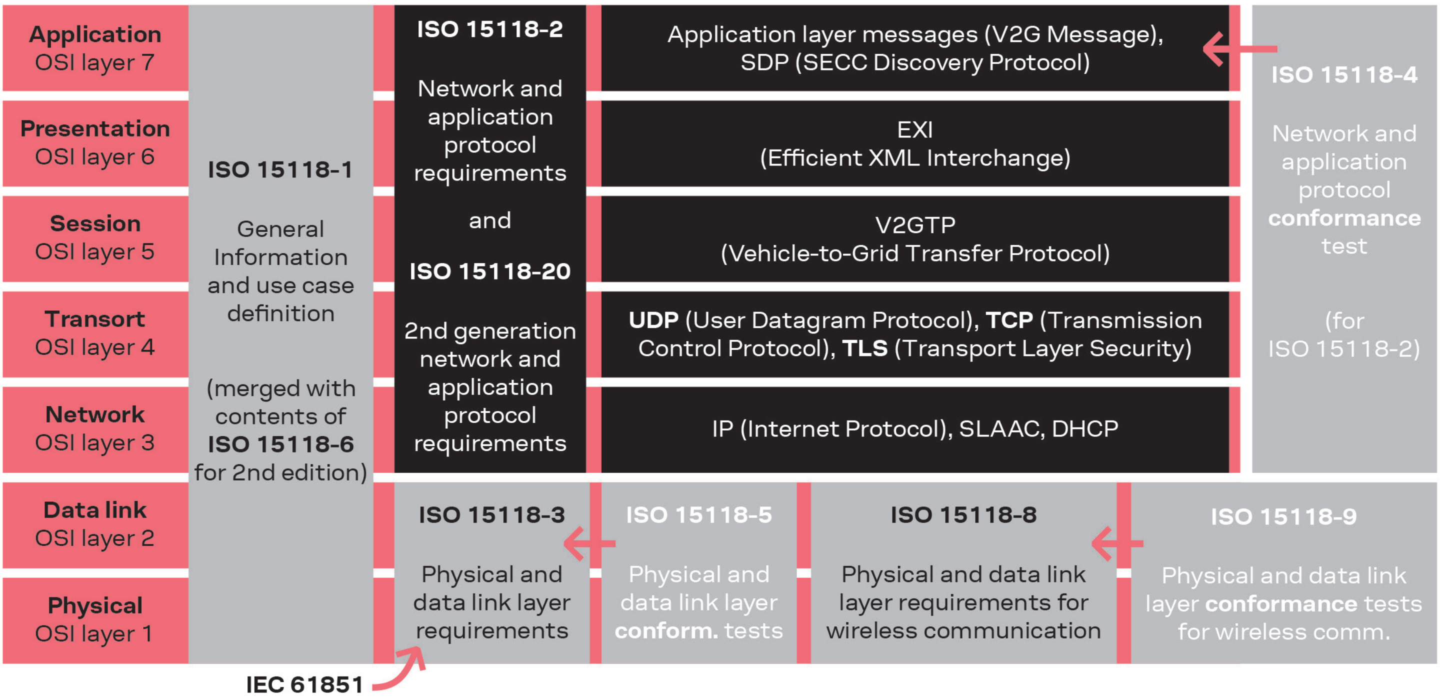
The initial configuration of the EV charging station, which includes entering the Wi-Fi and modem settings for back-end communication, can be made more user friendly by leveraging the rich graphical user interface offered by smartphones or tablets. Because of its ubiquity across smart devices, Bluetooth® low energy is an ideal wireless technology for this use case.

ISO 15118 for vehicle-to-grid communication

EVs are becoming ever more tightly integrated into the power grid, raising the importance of consistent communication between the EV, the charging station, and the power grid. Outlining vehicle-to-grid communication standards, ISO 15118 defines a standard communication interface to govern all aspects of the EV charging and billing process. In particular, ISO 15118 defines the procedures for setting up the communication session, including identification, authentication and authorization, fine positioning of the EV, target setting, energy transfer control, and disconnection.

The image below, adapted from V2G Clarity, an industry organization promoting user-friendly, secure, and interoperable EV charging, illustrates the components of the ISO 15118 standard and how they relate to the OSI layers.

ISO 15118 Parts and OSI Layers



The components of the ISO 15118 standard, adapted from V2G Clarity

Points to consider when deploying wireless technologies

Wireless connectivity will clearly play an essential role in creating a streamlined charging experience for end-users, who have grown accustomed to the highly optimized process of refueling their internal combustion engine vehicles. At first, conventional refueling will set the benchmark for the EV charging user experience. But looking further into the future, the EV charging process has the potential to exceed this benchmark by far, banking on countless opportunities for EV charging service providers to develop value-added services for their customers.

Wireless connectivity in the charging station

Because of the simplicity it offers, wireless connectivity will be essential to create a highly optimized user experience. We already see Wi-Fi play an increasingly important role in connecting the charging station to the EV (front-end connectivity) as well as to the cloud (back-end connectivity).

Wi-Fi comes in many flavors, as does the hardware required to enable it. The following points offer guidance in selecting the most appropriate wireless technologies.

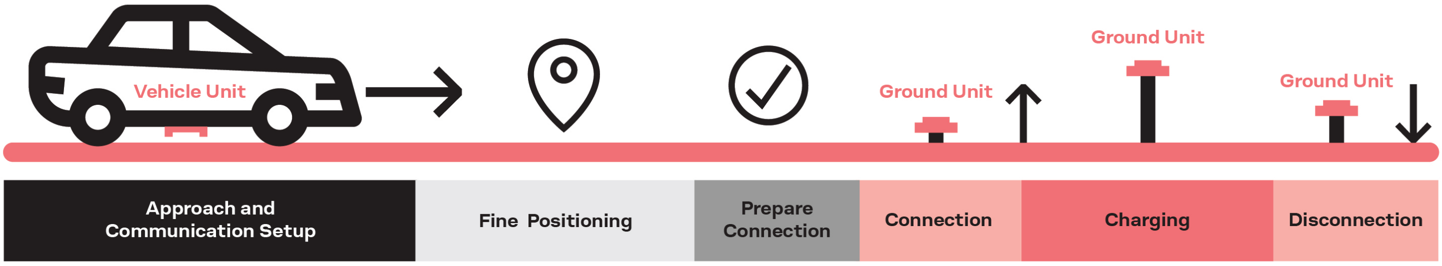
1 Back-end link: Bandwidth needs and location define the technology

Charging stations need a reliable and secure communications backbone for back-end communication. Bandwidth needs and the location of the charging station define the basic requirements. Often several means of communication, **typically Wi-Fi and cellular**, are implemented, offering flexibility to handle outages of either of the two networks.

Cellular connectivity is generally used in public charging stations for both four-wheeled EVs and increasingly for micromobility charging hubs that are deployed by municipalities across the globe to support fleets of shared e-scooters and e-bikes.

2 Front-end link: Wi-Fi part of the ISO 15118 standard

When it comes to front-end communication – between the charging station and the EV – **Wi-Fi is a natural choice**, not only for wireless EV charging. Wi-Fi is the only wireless technology to be included in the ISO 15118 standard and can play a vital role throughout the charging process. When the approaching vehicle is within Wi-Fi range, communication between the EV and the charging station starts, enabling certification handling, identification, authentication, and authorization. Next, Wi-Fi can be used to mediate fine positioning of the EV to connect to the charging station or optimize the conductive charging process. And finally, there is a negotiation phase where the targets are set and the energy transfer is scheduled. Other value-added services can be defined on top of this standard process.



The sequence of events involved in wireless EV charging, which requires a wireless communication channel between the charging station and the vehicle.

3 Wi-Fi connectivity: Future-proof designs with dual-band Wi-Fi and Wi-Fi 6

Because most use cases requiring Wi-Fi today have quite modest bandwidth requirements, existing implementations tend to use Wi-Fi 4, i.e. IEEE 802.11b/g/n, as this provides sufficient performance while reducing costs. But as demands on back-end communication increase and EV charging stations compete for bandwidth with a growing ecosystem of Wi-Fi and Bluetooth enabled devices, arguments in favor of later releases of the standard are gaining in force. Many implementations use dual-band Wi-Fi (2.4 GHz, 5 GHz) for increased reliability, flexibility, and capacity. Going forward, Wi-Fi 6 will further increase reliability in crowded signaling scenarios where large numbers of devices compete for limited bandwidth.

4 Wi-Fi and Bluetooth: Multiradio modules save space and reduce costs

Because of the ubiquity of Bluetooth on smartphones, tablets, and other devices, the technology is ideal for initial local configuration and later maintenance purposes by a technician. Rather than necessitating a dedicated human-machine interface, the technician can configure advanced settings and perform firmware upgrades using an app running on a smart device. This may justify opting for a Wi-Fi and Bluetooth multiradio module.

Managing front-end and back-end Wi-Fi communication using the same module can further reduce the bill of materials. In such a setup, the module concurrently acts as a Wi-Fi station and as a Wi-Fi access point for the EV. Alternatively, Wi-Fi direct can be used to connect the EV to the charging station without requiring an intermediary Wi-Fi access point.

5 Cellular technology selection: Bandwidth requirements and availability narrow down the choice

Offering simplified authentication, cellular technology is an optimal form of wireless connectivity to establish a resilient end-to-end connection to the power distributor's back-end booking and billing infrastructure for both public and private charging stations that lack a continuous Wi-Fi connection to a local gateway.

Which flavor of cellular technology is most appropriate will depend on the bandwidth and coverage requirements of the use-case. 2G and 3G connectivity continue to be relevant in several markets, while LTE-M and LTE Cat 1 are becoming the dominant technologies in new deployments of cellular-enabled EV terminals.

With its good price-performance ratio, LTE- M technology meets the connectivity needs of mainstream EV charging stations with sufficient bandwidth and short enough latencies to manage typical tasks such as monitoring the occupancy of fielded charging units and remotely controlling the charging and billing process.

Enhanced radio signal propagation (+15 dB compared to legacy 2G technology) lets LTE-M reach charging stations installed underground or in other hard-to-reach places.

The larger bandwidth offered by LTE Cat 1 makes it suitable for deployments requiring frequent firmware-over-the-air (FOTA) campaigns with large firmware image sizes as well as for more complex charging stations, equipped, for example, with high resolution displays used to stream images and video content for added value advertising and information services.

6 Application design: The host environment defines the module type

Charging stations featuring large displays with advanced graphical user interfaces typically require a powerful host CPU running Linux. These scenarios call for **host-based Wi-Fi or multiradio** modules. In this case, the IP-stack and Wi-Fi drivers run on the host CPU, with the Wi-Fi module running the lower communication layers (PHY, MAC).

In the case of simpler charging stations, for example, domestic charging points, **stand-alone modules** controlled via AT-commands will typically be the best fit. Stand-alone modules come fully equipped with a Wi-Fi software stack and offer basic communication services out of the box.

7 Product grade: Harsh environments demand automotive-grade products

Weighing the pros and cons of selecting costlier automotive-grade modules may not seem obvious. Today, most charging stations use communication modules qualified for standard industrial applications. That being said, EV-charging stations often operate in harsh environments, which may provide arguments in favor of **automotive-grade modules**. Qualified according to ISO 16750 / AEC Q104, these modules feature excellent immunity to severe mechanical and electrical stress. They are characterized by the lowest possible field failure rate, offer long-term product availability to support the automotive industry's product life cycles, and come with automotive quality processes (PPAP, 8D, failure analysis).

Wireless connectivity in the EV

In the electric vehicle itself, the EV charging system can run on a variety of host environments, which are defined by an operating system and an MCU/CPU/MPE. The safe exchange of critical charging information between the EV and the charging station is essential, as is compliance with automotive software standards and assessment models.

8 Product grade: Automotive by mandate

For the implementation of the Wi-Fi connection in the EV, automotive-grade modules are required by mandate. Qualified strictly according to ISO 16750 / AEC Q104, these modules feature excellent immunity to severe mechanical and electrical stress, as mentioned above. They are characterized by the lowest achievable field failure rates, offer long-term product availability to support the automotive industry's product life cycles, and are designed according to automotive quality processes (PPAP, 8D, failure analysis). They often comply with automotive software standards and assessment models such as AUTOSAR, MISRA, and Automotive SPICE.

9 In-vehicle solution architecture: Host-based implementations may require porting the driver and stack to the host environment.

In a common scenario, the EV charging system runs on a dedicated EV charge controller unit that is managed by an AUTOSAR based MCU. To handle Wi-Fi, it requires an automotive-grade Wi-Fi module connected via a serial interface (SPI) or SDIO. Such implementations often require porting the driver and the stack software to the target host environment.

5 Conclusions

The wireless charging market is booming as a growing number of individuals and businesses are opting for electric vehicles (EVs) for their reduced environmental impact, low operation and maintenance costs, and, crucially, government monetary and non-monetary subsidies. Popularizing these solutions will require making EV charging as straightforward as, or more straightforward than, refueling conventional ICE vehicles.

Wireless technologies will play an essential role in connecting charging stations and EVs to control the charging process. By connecting charging stations and third-party service providers, they will also be essential to improve the EV charging user-experience, for instance, by making it easy to find free charging stations, simplifying billing, and offering a variety of other value-adding services. And they will be key to enabling vehicle-to-grid communication as EVs are relied on to help smoothen supply and demand on the power grid.

In this white paper, we provided an overview of the wireless connectivity technologies that can be used to enable and control the EV charging process, covering front-end communication between the EV charging station and the vehicle itself, as well as back-end communication between the EV charging station and the cloud, and offered recommendations on their implementation into successful solutions.

Appendix I: Technology considerations

Wi-Fi

The table below outlines key considerations regarding the choice of Wi-Fi components.

Feature/Capability	EV Charging Station		EV
	Back-end communication	**Front-end communication**	**Front-end communication**
Architecture	Stand-alone/Host-based	Host-based	Host-based
Wi-Fi single band or dual band	Single band/dual band	Dual band	Dual band
Multi-mode (Wi-Fi/Bluetooth LE)	Multi-mode or Wi-Fi only	Wi-Fi only	Wi-Fi only
LTE filter	May be applicable if EV charging station also has LTE connectivity		May be applicable in specific cases
Simultaneous Wi-Fi access point and station	Yes, if EV charging station should support both back-end and front-end communication		No
Wi-Fi release	Wi-Fi 4, Wi-Fi 5 or Wi-Fi 6		Wi-Fi 4 or Wi-Fi 5
Grade	Professional/Automotive		Automotive

Bluetooth

The outlines key considerations regarding the choice of Bluetooth components.

Feature/Capability	EV Charging Station	EV
Configuration		
Architecture	Stand-alone (Bluetooth only)/Host-based (Multi-mode)	NA
Bluetooth 5	Yes	NA
Multi-mode (Wi-Fi/Bluetooth LE)	Multi-mode or Bluetooth only	NA
Bluetooth LE 2 Mbps PHY	Yes	NA
Bluetooth LE long range	Limited value	NA
Grade	Professional/Automotive	NA

Cellular

The table below outlines key considerations regarding the choice of cellular components.

Charging Unit Type	Domestic charging box	Hotels, small retail, workplace, charging networks	Public charging stations, Micromobility EV charging hubs	High-end public pole station
MCU	Low complexity MCU	Low complexity MCU	Low complexity MCU	Cortex Ax and higher
OS type	RTOS	RTOS	RTOS	Linux or other full-feature OS
Display/Multimedia complexity	no display	no display or low feature display	no display or low feature display	mid- to high-end
Bandwidth requirements	low	low	low	mid
Cellular connectivity	none	LTE-M	LTE-M	LTE Cat1

Appendix II: u-blox solutions

u-blox offers a range of connectivity solutions that are tailored to the needs of EV charging applications.

Wi-Fi

The main candidates for Wi-Fi are outlined in the following table.

	LILY-W1	MAYA-W1	JODY-W2	JODY-W3	ODIN-W2	NINA-W1
Architecture	Host-based	Host-based	Host-based	Host-based	Stand-alone	Stand-alone
Wi-Fi single band or dual band	Single band	Dual band	Dual band	Dual band	Dual band	Single band
Multi-mode (Wi-Fi/Bluetooth low energy)	Wi-Fi only	Multi-mode	Multi-mode	Multi-mode	Multi-mode	Multi-mode or Wi-Fi only
LTE filter	Yes	Yes	Yes	Yes	No	No
Simultaneous Wi-Fi access point and station	Yes	No	Yes	Yes	No	Yes
Wi-Fi release	Wi-Fi 4	Wi-Fi 4	Wi-Fi 5	Wi-Fi 6	Wi-Fi 4	Wi-Fi 4
Wi-Fi Alliance certification	No	No	No	No	No	Yes
Grade	Professional	Professional	Professional/ Automotive	Professional/ Automotive	Professional	Professional

Bluetooth

The following table outlines the most appropriate u-blox solutions for Bluetooth connectivity.

	NINA-B1	NINA-B3	NINA-B4	NORA-B1	ANNA-B1	NINA-W1	ODIN-W2	MAYA-W1	JODY-W2	JODY-W3
Architecture	Stand-alone	Stand-alone	Stand-alone	Stand-alone	Stand-alone	Stand-alone	Stand-alone	Host-based	Host-based	Host-based
Bluetooth version	Bluetooth 5	Bluetooth 5	Bluetooth 5.1	Bluetooth 5.2	Bluetooth 5	Bluetooth 4.2	Bluetooth 4.2	Bluetooth 5.1	Bluetooth 5.1	Bluetooth 5.1
Multi-mode (Wi-Fi/ Bluetooth low energy)	Bluetooth LE	Bluetooth LE+Thread/ ZigBee	Bluetooth LE+Thread/ ZigBee	Bluetooth LE+Thread/ ZigBee	Bluetooth LE	Wi-Fi+ Bluetooth dual mode	Wi-Fi+ Bluetooth dual mode	Wi-Fi+ Bluetooth dual mode	Wi-Fi+ Bluetooth dual mode	Wi-Fi+ Bluetooth dual mode
Bluetooth LE 2Mbps PHY	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Bluetooth LE long range	No	Yes	Yes	Yes	No	No	No	Yes	No	Yes
Grade	Professional	Professional	Professional	Professional	Professional	Professional	Professional	Professional	Professional/ Automotive	Professional/ Automotive

Cellular

The following table outlines the most appropriate u-blox solutions for cellular connectivity

	SARA-R422S	SARA-R510S	LARA-R2xx
Cellular connectivity	LTE-M w 2G fallback	LTE-M	LTE Cat 1 regional variants
Domestic charging box	X	X	
Small commercial charging networks	X	X	
Public charging stations, Micromobility EV charging hubs	X	X	X
High-end public charging station			X

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About the author

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Stefan Berggren is Senior Product Marketing Manager in the Product Center Short Range Radio at u-blox. In his role, he manages business development and product marketing activities related to short range radio solutions for the industrial segment, with a special focus on Bluetooth and Wi-Fi technologies used in smart buildings and smart cities.

Stefan joined u-blox in 2016. He has over 20 years of experience in the mobile telecom industry in various management positions within product management, sales & marketing, and R&D/CTO at companies including Ericsson, ST-Ericsson, and Telia. He holds a Master of Science in electrical engineering from Lund University, Sweden.

About u-blox

u-blox (SIX:UBXN) is a global provider of leading positioning and wireless communication technologies for the automotive, industrial, and consumer markets. Its solutions let people, vehicles, and machines determine their precise position and communicate wirelessly over cellular and short range networks.

With a broad portfolio of chips and modules, and a growing ecosystem of product supporting data services, u-blox is uniquely positioned to empower its customers to develop innovative solutions for the Internet of Things, quickly and cost-effectively.

With headquarters in Thalwil, Switzerland, the company is globally present with offices in Europe, Asia, and the USA.

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