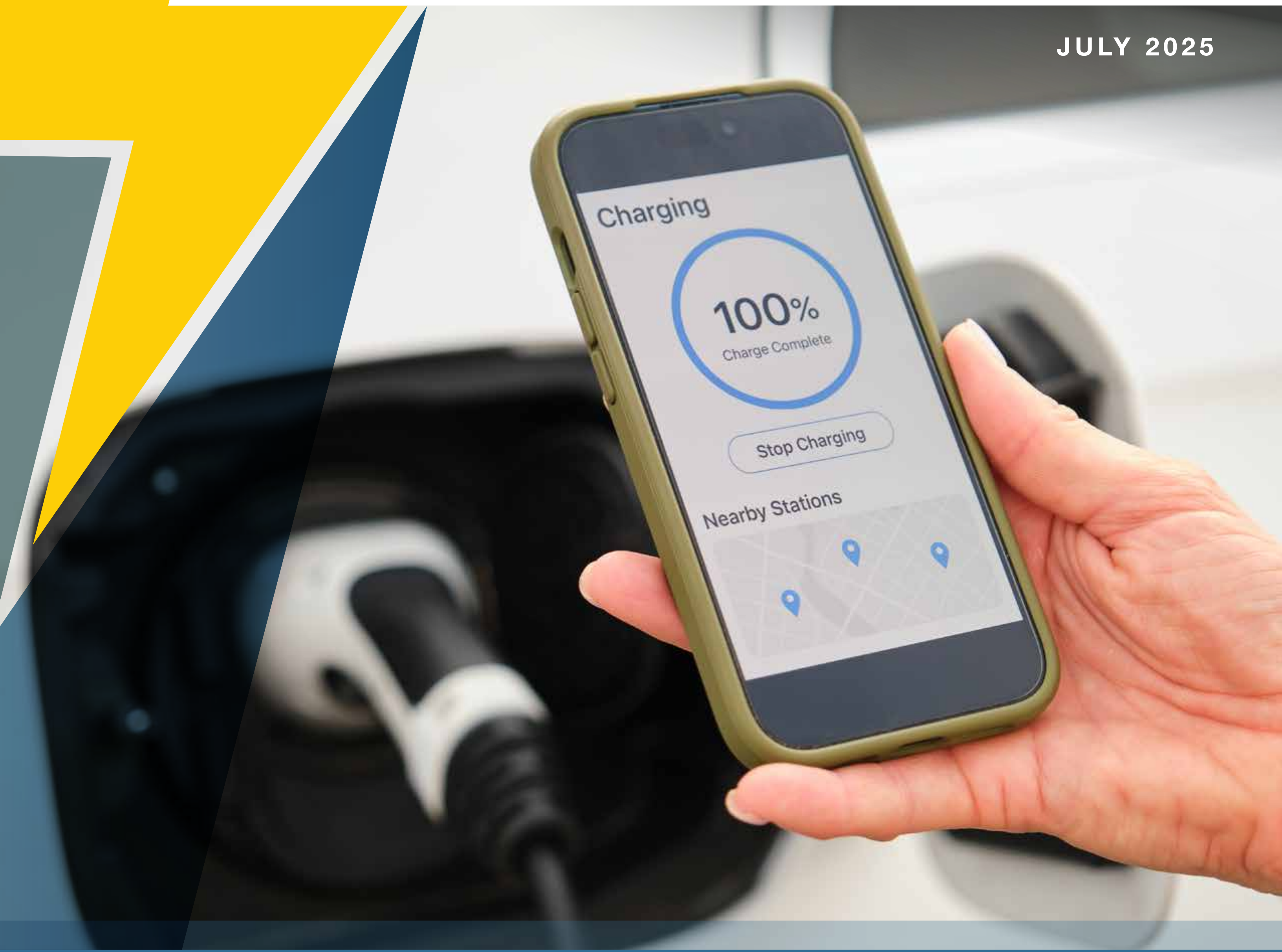
Quantifying
Time to Charge

CHARGEX consortium

JULY 2025



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List of Acronyms

AC	alternating current
ChargeX	National Charging Experience
DC	direct current
EV	electric vehicle
EVSE	electric vehicle supply equipment
PnC	Plug and Charge
SECC	supply equipment communication controller
SLAC	signal level attenuation characterization
TLS	Transport Layer Security

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1 Introduction

This study investigates the duration of the phases required to initialize a charging communication session between electric vehicles (EVs) and EV chargers. It identifies the highest-duration phases and proposes recommendations to reduce the overall charge session initialization duration (time to charge). A typical EV charging session consists of multiple phases, starting with a user plugging a charging connector into an EV, continuing through the initialization phase until energy transfer begins, and terminating once the requested energy has been delivered to the EV.

Each of these phases serves an important and distinct function. These can be broadly categorized based on their functions into (in order of occurrence): setting up the lower-level communication layers (pre-application layer), supply equipment communication controller (SECC) discovery, application protocol negotiation, initiating vehicle-to-grid communication session, service negotiation, payment authorization, charge parameter negotiation/compatibility checks, verifying electrical integrity of the connector, and voltage matching.

1.1 Motivation

This report is motivated by the desire to improve the customer experience and reliability of EV charging. Enabling faster charge session initialization improves the immediate customer experience by reducing the time users need to wait to confirm that their charge session is successfully underway. Perhaps more importantly, a faster initialization process can work in tandem with diagnostics and retry mechanisms (e.g., seamless retry) to get to a higher rate of first-time plug-in success. Reducing time to charge also means that if a session is going to fail, it can fail faster, and either the setup can be attempted again or the driver can be directed to a different action, minimizing the uncertainty and hassle for the end user. Finally, minimizing the time-to-charge process can also help enable new features (e.g., smart charge management schedule exchange), which might otherwise push the charge initialization process to longer durations.

1.2 Scope

This work focuses exclusively on EV charging sessions that use high-level communication as defined in open EV charging protocols such as the International Organization for Standardization’s ISO 15118-2, German Institute for Standardization’s DIN SPEC 70121, SAE International’s SAE J2847/2 and J1772, and other relevant charging standards. The focus of this document is direct current (DC), but the first part of the analysis focuses on both DC and alternating-current (AC) EV charging with high-level communication.

1.3 Methodology

We achieve the goal of this study by analyzing communication logs between EVs and electric vehicle supply equipment (EVSE) for EV charging sessions from multiple sources to quantify the duration of each phase. Following this, we identify the highest-duration phases and thoroughly review their requirements. Finally, where possible, we present improvements to speed up the execution of these phases.

2 Quantifying and Improving Time to Charge

2.1 Quantifying Time to Charge

This section outlines the methodology and presents the results from an analysis of charging session communication logs.

Input Data

The input data utilized for this analysis consist of packet captures. One subset of these packet captures was recorded directly by the EVSE during the charging session. The remainder of the data files were captured with an inductively coupled third-party data recorder. Although both methods can record the packets exchanged between the charger and the vehicle, some packets may not be detected or may be dropped when using the inductively coupled method. The total number of tests used for the analysis is 162.

The captured charging sessions fall into three main categories:

1. Sessions conducted on public chargers with production EVs.
2. Tests conducted in a lab environment with lab-owned EVs and lab-owned non-public chargers.
3. Peer-to-peer tests conducted on non-production/pre-production EVSE using a combination of production and pre-production EVs.

Figure 1 shows the percentage of each test category relative to the total number of tests.

The data used in this analysis come from two sources: the EVerest logfile database, which is publicly available on GitHub,[1] and additional data collected by the National Charging Experience (ChargeX) lab team. All files are in PCAP format. Timing analysis is performed using the beginning of the signal level attenuation characterization (SLAC) phase as the reference frame, as plug-in times are not available within the input dataset. Similarly, while control pilot and proximity pilot signals could lend additional context for this type of analysis, these datapoints are also not available.

Note: The test data do not include any results with the Transport Layer Security (TLS) protocol or Plug and Charge (PnC). Because the number of tests is relatively small, the captured files and analysis results may not fully represent the state of the industry. The conclusions in this report should be interpreted as an objective analysis of the available test data. Specifically, as some tests were conducted in a laboratory environment or on peer-to-peer non-production/pre-production EVSE and EVs, the authentication phase may differ from results obtained from public chargers.

[1] "EVerest/logfiles: Logfiles from testing with real cars." GitHub. Accessed Jan. 22, 2025. github.com/EVerest/logfiles.

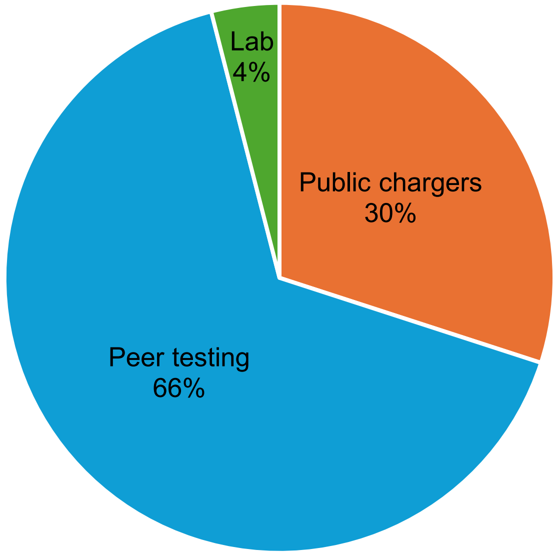

Figure 1. Categories of test data sources

Figure 2 shows the distribution of communication protocols between the EVSE and EVs (DIN SPEC 70121, ISO 15118-2 DC, and ISO 15118-2 AC).

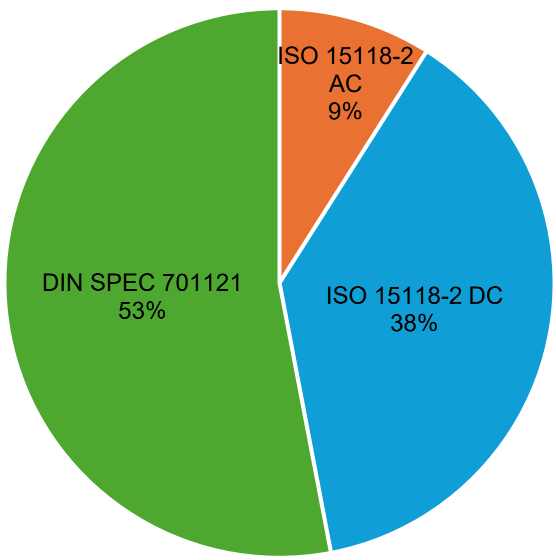

Figure 2. Distribution of communication protocols used in the tests

Analysis/Methodology

A Python script, in combination with TShark (a command-line version of Wireshark for capturing and analyzing packets), is used to convert all PCAP files to CSV format. The remaining analysis is then performed using MATLAB.

Results/Takeaways

This section summarizes the results of the statistical analysis and draws conclusions about the time delays in each phase before charging begins.

Figure 3 presents graphs depicting the total time taken from the start of the SLAC phase to the Session Setup and Power Delivery phases.

For the Session Setup phase, the first quartile (the time below which 25% of the data fall) is 3.01 seconds, while the third quartile (the time above which 75% of the data falls) is 6.56 seconds. The median time is 4.44 seconds, and the average time is 8.57 seconds.

For the Power Delivery phase, the first quartile is 12.05 seconds, and the third quartile is 43.08 seconds. The median time for this phase is 26.99 seconds.

Figure 3. Times to reach Session Setup and Power Delivery phases

Figure 4 and Figure 5 illustrate the time taken in different phases. Among all phases, the Cable Check phase had the longest duration, with a median time of 6.87 seconds and an average time of 13.5 seconds. This was followed by the Pre-Charge phase, which had a median time of 2.0 seconds and an average time of 3.11 seconds.

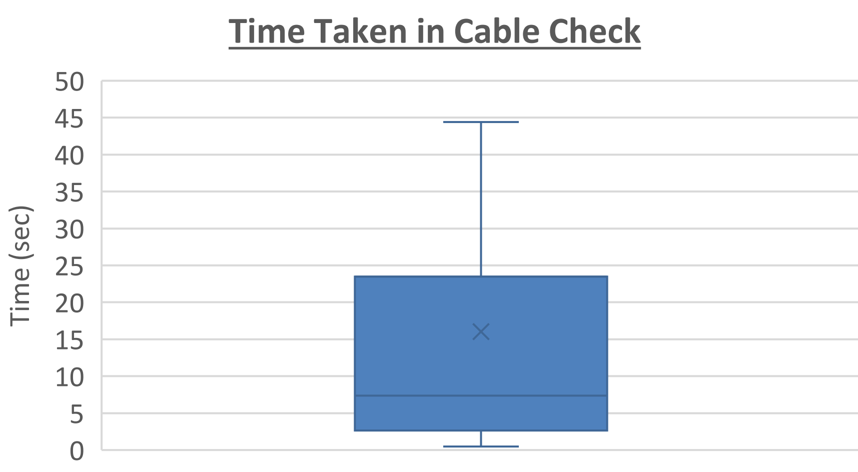

Figure 4. Time taken in the Cable Check phase

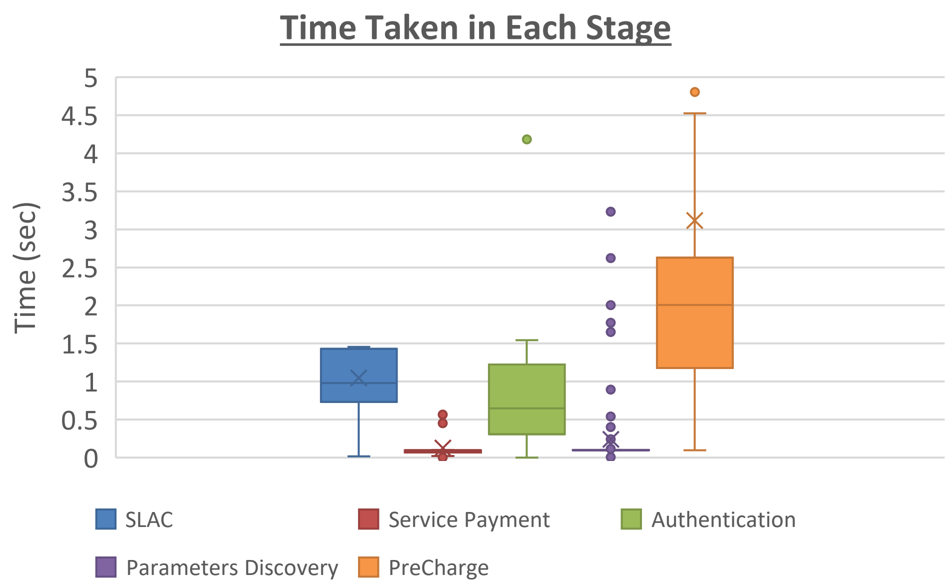

Figure 5. Times taken in SLAC, Service Payment, Authentication, Parameters Discovery, and Pre-Charge phases

These analysis results were presented to industry participants during the ChargeX Consortium's Communications Task Force monthly meeting on Feb. 19, 2025. There was a general consensus in agreement with the conclusions. Specifically, several participants acknowledged that among all phases preceding the start of charging, the Cable Check phase typically takes the longest duration.

2.2 Improving Time to Charge

This section presents a review of the charge session initialization phases that offer the most potential for reducing the time to charge.

Overview

Section 2.1 shows that the three largest contributing phases to time to charge are Cable Check, Authentication, and Pre-Charge. Time allowed in the Cable Check and Pre-Charge phases is governed by the EV charging protocols and specific implementations. In contrast, time spent in the Authentication phase is affected by a combination of user interaction, payment methods used, and the back-end system used to authorize the payment. With the data available for this analysis, the user interaction portion of Authentication cannot be disentangled from the other factors. Therefore, this study does not focus on analyzing or finding ways to reduce time taken in the Authentication phase.

Cable Check

Cable Check is the phase of charging session initialization in which the charger verifies that it can safely exchange energy with the EV. The charger achieves this by making an insulation resistance measurement between DC+, DC−, and protective earth. The charger then compares the measured value to minimum thresholds set by relevant standards. This measurement occurs before the contactors on the EV are closed (i.e., before the charger is connected electrically to the EV's battery) and ensures that the charging hardware, cable, and EV inlet are all safe to operate. The Cable Check phase is only performed for DC charging. AC charging does not require this phase. It is preceded by the Charge Parameter Discovery phase and followed by the Pre-Charge phase.

The EV communications controller begins the Cable Check phase by sending a Cable Check Request message to the SECC. The SECC responds with a Cable Check Response message. Often, multiple rounds of request and response messages are required to keep the EV communications controller and SECC in communication while the charger performs the required safety checks. Once these checks are completed and verified, the SECC then sends a final Cable Check Response message indicating the completion of the phase.

The timing requirements relevant to the Cable Check phase are primarily found in ISO 15118-2:2014 and IEC 61851-23:2023-12(en). Figure 6 presents a graphical representation of the timing requirements in the Cable Check phase.

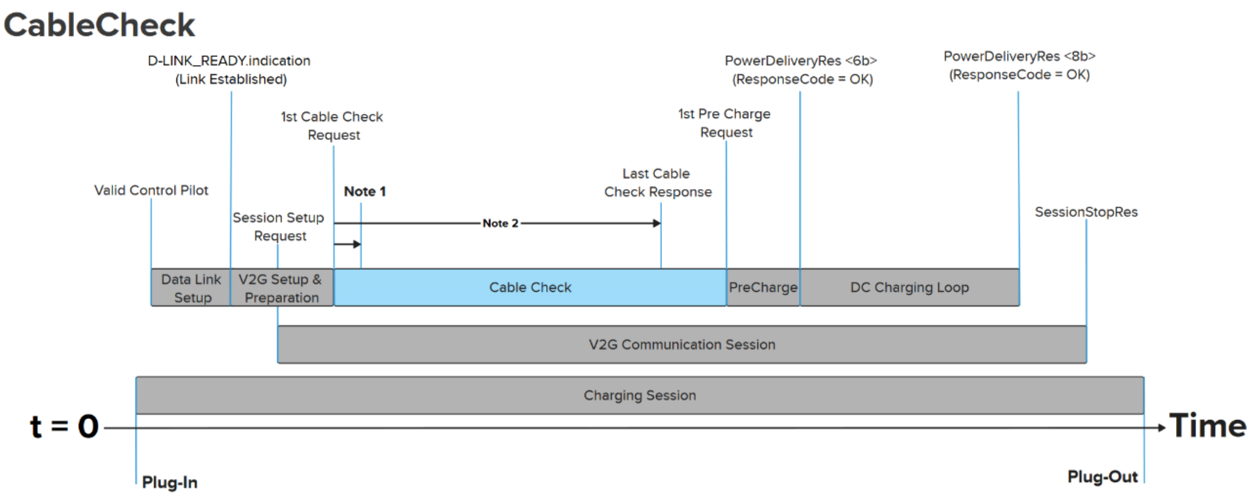

Figure 6. Cable Check diagram

Note 1: Present voltage at EVSE's DC output holds test value for at least 1 s (IEC 61851-23:2023-12(en)).
Note 2: EVSE must complete the Cable Check process within 40 s (ISO 15118-2:2014).

ISO 15118-2 limits the overall duration of the Cable Check phase to 40 s. IEC 61851-23 requires that the charger maintain a specific voltage level (calculated based on the parameters exchanged in the Charge Parameter Discovery phase) for at least 1 s. Between these two requirements, there is a large window of time within which different implementations can operate. The analysis of charging session data presented in Section 2.1 reinforces this, as it shows a wide variation in the duration of this phase. In addition to a large variation in recorded values for the duration of the Cable Check phase, it is also often the longest-duration phase of charge session initialization.

Based on these factors, we highlight Cable Check as an area for potential improvement in reducing time to initialize a charging session. The actual mechanism of the insulation measurement during Cable Check is not dictated within the relevant charging standards, so duration in this phase largely reflects implementation-specific design choices. Based on the data reviewed and analyzed for this report, we recommend a target duration of 10–20 s for this phase.

Pre-Charge

The Pre-Charge phase is used to adjust the EVSE's output voltage to the EV's traction battery voltage. This is typically achieved using pre-charge circuits, which are designed to limit the electrical inrush current into bulk capacitors before enabling the entire high-voltage system. These circuits usually comprise a resistor and a high-voltage contactor.

The EV communications controller uses the PreChargeReq message to start the pre-charge process from the EV side. This message contains the EV's target voltage for the EVSE to match at its DC output. After receiving the PreChargeReq message, the SECC sends a PreChargeRes message informing the EV about its status and the present EVSE output voltage. The EVSE controls the present voltage at DC output according to the EV's target voltage.

There are several timing constraints imposed on the Pre-Charge phase in SAE J1772:2024-01, SAE J2847/2:2023-09, DIN SPEC 70121:2014, ISO 15118-2:2014, ISO 15118-20:2022, and IEC 61851-23:2023-12(en). These can be related to the message, sequence, or electrical requirements. Figure 7 puts the most relevant timing constraints into context within the overall charging session.

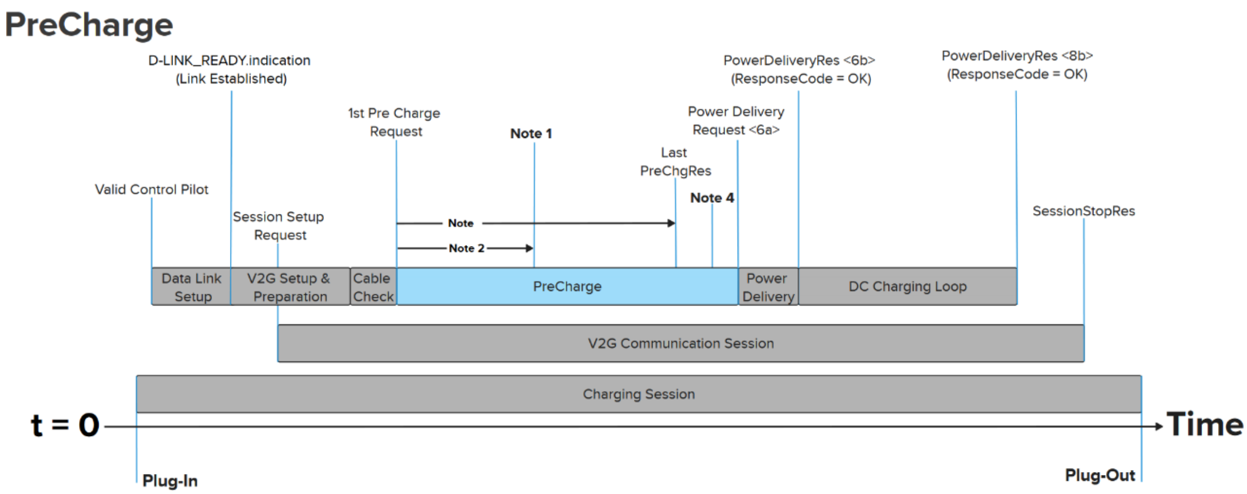

Figure 7. Pre-Charge diagram

Note 1: Present voltage at EVSE's DC output reaches EV's target voltage.
Note 2: EVSE shall be able to pre-charge the high-voltage DC bus in 3 seconds (SAE J1772:2024-01, IEC 61851-23:2023-12(en)).
Note 3: Overall process timeout of 7 seconds (DIN SPEC 70121:2014, ISO 15118-2:2014).
Note 4: EV closes charge contactors (SAE J1772:2024-01).

The Pre-Charge phase has an overall process timeout of 7 seconds as mentioned in all the relevant protocols except ISO 15118-20:2022, which imposes an overall process timeout of 10 seconds. This timeout is the one that affects time to charge the most because it bounds the overall time spent in the Pre-Charge phase.

The results from Section 2.1: Quantifying Time to Charge show that although the Pre-Charge phase is the second largest contributor to time to charge, its contribution is much smaller in magnitude compared to the largest contributor, Cable Check. The results also show that the variance in time spent in the Pre-Charge phase is quite minimal, indicating that the time required for pre-charging is reaching an equilibrium across the different pre-charging strategies used by industry. In addition to these factors, as discussed earlier, the maximum time allowed to be spent in this phase is limited to only 7 seconds before leading to the charging session timing out.

This leads to the conclusion that there is minimal room for improvement in reducing time spent in the Pre-Charge phase. This conclusion has been corroborated by the members of the ChargeX Consortium's Communications Task Force.

3 Conclusion and Future Work

This report quantifies the time it takes to initialize an EV charging session, breaking the process down into multiple phases. We analyzed charging session logs to generate an aggregated summary of the duration of each phase. We identified phases with the most potential for improvement based on variance within the dataset and each phase's share of the overall initialization duration. We then reviewed and summarized these phases, identifying constraints placed on timing by charging standards and proposing a recommended path forward for improvements.

There are a number of interesting possibilities for future work to build upon the analysis in this report. This analysis would benefit from being performed with a dataset that is more representative of the latest public charging ecosystem. Collecting additional charging session logs was not in the scope of this report, but a future effort would benefit from that type of directed data collection. This data collection effort would also benefit from targeting a few specific parameters: focusing on public chargers and production EVs, and including a wide variety of chargers and EVs, more ISO-15118-2 DC charging sessions, and TLS and PnC charging sessions. TLS and PnC charging sessions pose technical challenges with third-party PLC recordings and may only be possible with industry collaboration. Industry partners have indicated some initial time-to-charge issues related to TLS session setup. TLS session setup is required for PnC, and so because this technology is getting rolled out more widely, there is particular interest in applying the analysis from this report to those types of sessions.

Additionally, there are also efforts underway exploring the possibility of running certain phases of charge session initialization in parallel. Currently, these phases are all run in sequence. There is potential for significant reductions in time to charge if even some of these phases can instead be run simultaneously.

About the ChargeX Consortium

The National Charging Experience Consortium (ChargeX Consortium) is a collaborative effort between Argonne National Laboratory, Idaho National Laboratory, National Renewable Energy Laboratory, electric vehicle charging industry experts, consumer advocates, and other stakeholders. The ChargeX Consortium's mission is to work together to measure and significantly improve public charging reliability and usability by June 2025. For more information, visit chargex.inl.gov.

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