RECOMMENDED PRACTICE

SEAMLESS RETRY

for Electric Vehicle Charging

CHARGEX consortium

DECEMBER 2024

Argonne NATIONAL LABORATORY

INL Idaho National Laboratory

NREL Transforming ENERGY

Disclaimer

This report was prepared for the U.S. Department of Energy under DOE Idaho Operations Office Contract No. AC07-05ID14517. Funding was provided by the Joint Office of Energy and Transportation.

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List of Acronyms

AC	alternating current
DC	direct current
EV	electric vehicle
EVSE	electric vehicle supply equipment
HLC	high-level communications
V2G	vehicle to grid

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1 Introduction

This work introduces the concept of *seamless retry* in the electric vehicle (EV) charging domain. Its primary aim is to enhance the reliability and user experience of EV charging by reducing the frequency of user-required interventions in EV charging. This is achieved through a retry mechanism that can automatically activate upon encountering errors during the EV charging process.

1.1 Motivation

The motivation for developing the concept of seamless retry arises from the growing need for more reliable and user-friendly EV charging solutions. As the adoption of EVs continues to rise, the efficiency and robustness of charging infrastructure becomes increasingly critical. Particularly in the context of public direct-current (DC) fast charging, industry input indicates that after a charge session fails to properly initiate, a simple unplug and re-plug by the user can sometimes successfully start and complete a charging session. With the seamless retry mechanism in place, the customer will not need to manually unplug and re-plug their vehicle upon encountering an issue; instead, the process will be automated and invisible to the customer.

1.2 Scope

This work focuses exclusively on the application of the seamless retry mechanism within the realm of DC EV charging as defined within the International Organization for Standardization's ISO 15118,[1] German Institute for Standardization's DIN SPEC 70121,[2] and other relevant DC EV charging standards. Much of the mechanism described here can likely also be applied to alternating-current (AC) EV charging with high-level communications. However, additional work is needed to analyze and potentially modify what is presented here to ensure compatibility for AC EV charging.

2 Implementation of Seamless Retry

2.1 Overview

When a charge is initiated, communication between the vehicle and charger flows through several states, resulting in a successful charge or failure (see Appendix B for state definitions). The seamless retry mechanism utilizes these states to automate restarting a charging session without physical intervention. As shown in Figure 1, following the initial user plug-in, the seamless retry process can be initialized after a failed charge attempt. A failed charge attempt is defined here by the occurrence of an error or timeout after the control pilot signal has transitioned into State B2 with a 5% duty cycle. Seamless retry presents an automated error resolution process for all errors that can be resolved by a manual unplug and re-plug to increase

[1] International Organization for Standardization. 2019. *Road vehicles — Vehicle to grid communication interface — Part 1: General information and use-case definition*. Geneva, Switzerland. ISO 15118. www.iso.org/standard/69113.html.

[2] European Standards. 2014. *Electromobility - Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging in the Combined Charging System*. DIN SPEC 70121. www.en-standard.eu/din-spec-70121-electromobility-digital-communication-between-a-d-c-ev-charging-station-and-an-electric-vehicle-for-control-of-d-c-charging-in-the-combined-charging-system-text-in-english/.

the likelihood of successfully initiating a charge. This is done by an automated transition back to State B1, where both the EV and electric vehicle supply equipment (EVSE) reset all state variables and timers related to the execution of a single charge attempt. This reset emulates the conditions present immediately after the transition from State A to B1, thus preparing the system for a new charge attempt.

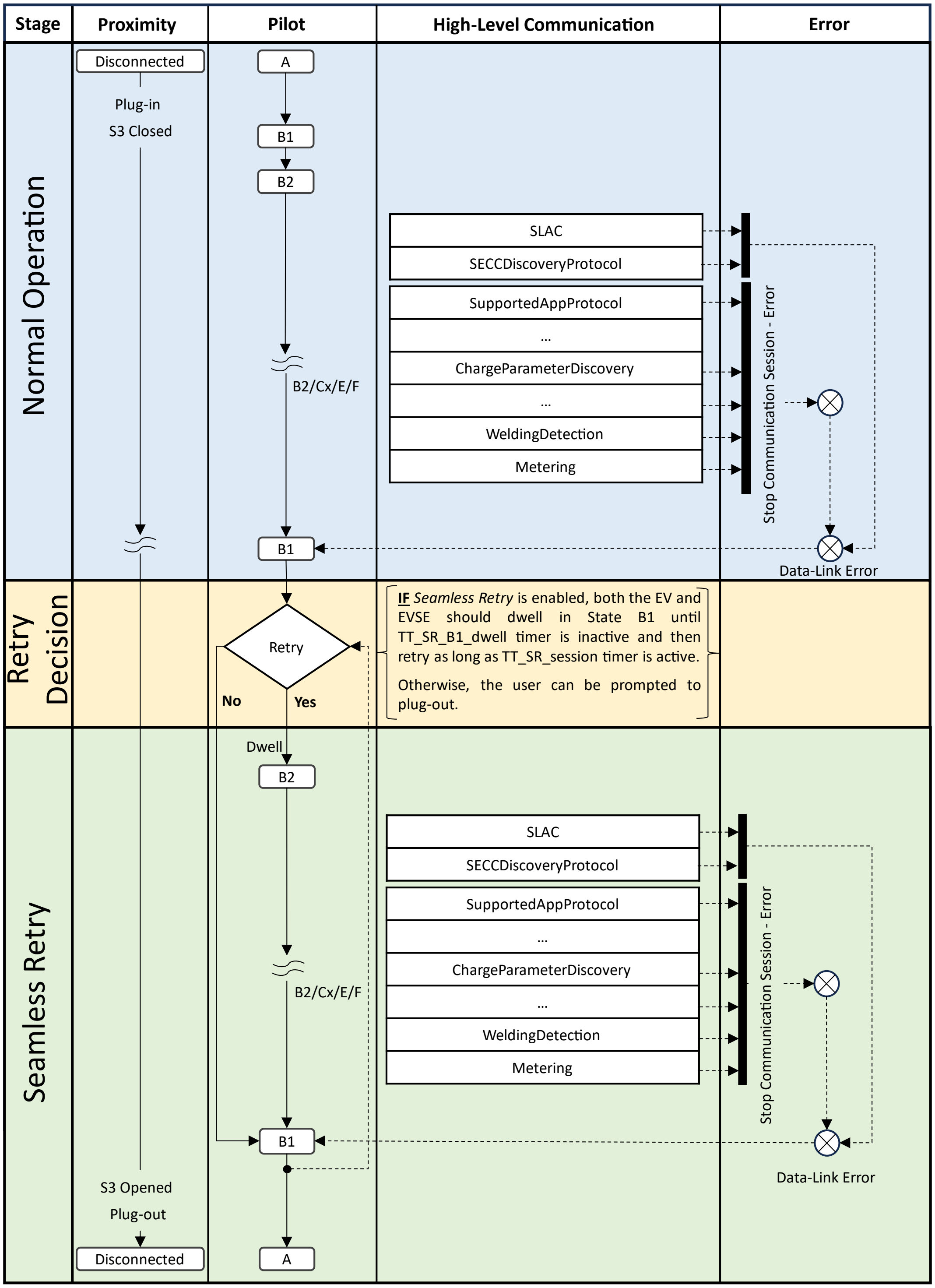

Figure 1. Overview of the seamless retry mechanism

Continuing from the initialization of the charging procedure, Figure 1 illustrates the comprehensive sequence of state transitions. Upon encountering a failed charge attempt following State B2 with a 5% duty cycle, the system can avoid the typical manual unplug requirement. Here, a decision point shall assess whether conditions are favorable for a retry. Required and recommended criteria for this decision point are defined in subsequent sections. If affirmative, and if both parties have implemented seamless retry, the EV and EVSE shall dwell in State B1 until the TT_SR_B1 timer has elapsed, allowing for a reset of all state variables and timers related to the execution of a single charge attempt between the EV and EVSE. After the TT_SR_B1_dwell timer has elapsed, the EVSE shall transition to State B2, reinitiating the vehicle-to-grid (V2G) communication setup procedures essential for DC charging the EV. If the charging session is successfully established, the charging procedure shall advance as normal. Conversely, if the charge attempt fails and the conditions for seamless retry are no longer met, the system should transition to a shutdown state, indicated by a return to State B1, and eventually to the disconnected State A, with the user being duly notified of the unsuccessful attempts. Figure 1 and Figure 2 provide a clear overview of the retry logic, emphasizing the user-free intervention aspect of the seamless retry mechanism.

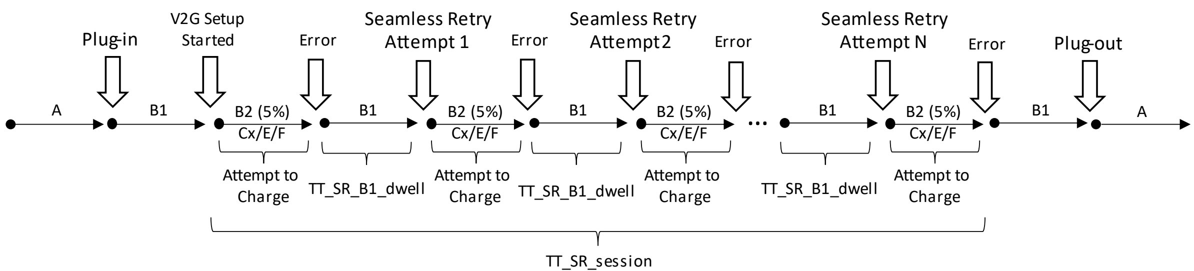

Figure 2. Timeout handling under the seamless retry procedure

2.2 EVSE Requirements

This section details the technical requirements for implementing the seamless retry mechanism on the EVSE side.

Seamless Retry Mechanism

[SR-02B-01] If the EVSE detects a failed charge attempt and the TT_SR_session timer is active, the EVSE shall transition to State X1.

[SR-02B-02] If the EVSE has detected a failed charge attempt and detects State B1, the EVSE will dwell in State B1 for the time specified by TT_SR_B1_dwell. After the time specified by TT_SR_B1_dwell has elapsed, if the TT_SR_session timer is active, the EVSE shall then transition to State B2 (with a 5% duty cycle) and begin a new charge attempt.

Note: When the state transitions to X1 after a failed charge attempt, the EVSE should reset all state variables and timers related to the execution of a single charge attempt. However, any input from the user (e.g., payment authorization) should be retained across attempts when possible.

[SR-02B-03] If during a seamless retry attempt the EVSE has completed the state transitions required to trigger a new charge attempt and the EVSE does not detect the expected match request from the EV within the allotted time, the EVSE may then add State E and/or State F in the transition on subsequent attempts. The EVSE should dwell in State E/F for the time specified by TT_SR_B1_dwell, and these transitions would be executed as follows: State B1 → State E/F → State B1 → State B2 (with a 5% duty cycle).

Note: Some EVs, legacy vehicles in particular, will trigger a fault if State E or State F is detected. In these vehicles, this fault will persist and will not allow any further charge attempts until the charging connector is manually unplugged and re-plugged.

Seamless Retry Session Management

[SR-02B-04] Upon the first transition into State B2 (with 5% duty cycle) following plug-in (A → Bx/E/F transition), the EVSE shall reset and start the TT_SR_session timer. If the TT_SR_session timer is inactive, the TT_SR_session timer may be triggered again (reset and restarted) by the first transition into State B2 (with a 5% duty cycle) following an EV-initiated wake-up as defined in Section 7.6 of ISO 15118-3.

[SR-02B-05] If the TT_SR_session timer exceeds the chosen TT_SR_session value, the EVSE shall consider the TT_SR_session timer inactive, and the EVSE shall stop monitoring the TT_SR_session timer.

[SR-02B-06] If the following triggers occur, the EVSE shall consider the TT_SR_session timer inactive, and the EVSE shall stop monitoring the TT_SR_session timer:

- TT_SR_session timer exceeds the chosen TT_SR_session value.
- Transition to State A (i.e., unplug as detected on proximity).
- User-initiated shutdown (initiated on EVSE side).
- Successful charge session completed with normal shutdown.

[SR-02B-07] If the TT_SR_session timer transitions to an inactive state during a charge attempt, this transition shall not trigger the EVSE to interrupt the charging attempt.

2.3 EV Requirements

This section details the technical requirements for implementing the seamless retry mechanism on the EV side.

Seamless Retry Mechanism

[SR-02C-01] If the EV detects a failed charge attempt and the TT_SR_session timer is active, the EV shall transition to State Bx.

[SR-02C-02] If the EV has detected a failed charge attempt and detects State B1 and the TT_SR_session timer is active, the EV shall be prepared to begin a new charge attempt within the time specified by TT_SR_B1_dwell.

[SR-02C-03] If the state transitions from State B1 to State B2 (with a 5% duty cycle) after a charge attempt failure, and if the TT_SR_session timer is active, the EV shall begin a new charge attempt.

Note: When the state transitions to Bx after a failed charge attempt, the EV should reset all state variables and timers related to the execution of a single charge attempt. However, any input from the user (e.g., payment authorization) should be retained across attempts when possible.

[SR-02C-04] State transitions through State E and/or State F should not prevent the EV from attempting to start a new charge session.

Seamless Retry Session Management

[SR-02C-05] Upon the first transition into State B2 (with a 5% duty cycle) following plug-in (A → Bx/E/F transition), the EV shall reset and start the TT_SR_session timer. If the TT_SR_session timer is inactive, the TT_SR_session timer may be triggered again (reset and restarted) by the first transition into State B2 (with a 5% duty cycle) following an EV-initiated wake-up as defined in Section 7.6 of ISO 15118-3.

[SR-02C-06] If the TT_SR_session timer exceeds the TT_SR_session value, the EV shall consider the TT_SR_session timer inactive, and the EV shall stop monitoring the TT_SR_session timer.

[SR-02C-07] If the following triggers occur, the EV shall consider the TT_SR_session timer inactive, and the EV shall stop monitoring the TT_SR_session timer:

- TT_SR_session timer exceeds the TT_SR_session value.
- Transition to State A (i.e., unplug as detected on proximity).
- User-initiated shutdown (initiated on EV side).
- Successful charge session completed with normal shutdown.
- AC basic charging is indicated by the EVSE (i.e., nominal duty cycle is detected on the pilot control signal).

[SR-02C-08] If the TT_SR_session timer transitions to an inactive state during a charge attempt, this transition shall not trigger the EV to interrupt the charging attempt.

[SR-02C-09] If the EV detects a transition from State B1 to State B2 (with a 5% duty cycle) after a failed charge attempt and the TT_SR_session timer is inactive, the EV may ignore this state transition.

Note: Under certain conditions, the EV may not want to ignore this state change. For example, the EV may want to respond to a wake-up from the EVSE after some extended period of time.

2.4 Timing and Parameters

Table 1. Timing and Constant Values

Parameter	Description	Min.	Typical	Max.	Unit
TT_SR_B1_dwell	Minimum time for dwell in State B1 after a failed charge attempt before proceeding to State B2 (with a 5% duty cycle)	4	5	10	s
TT_SR_session	Timeout	160	–	610	s

2.5 Recommendations

User Experience

In many cases, the seamless retry mechanism will improve the charging experience for the end user. Specifically, if the user is not paying close attention to the status of the charge session (e.g., if a user completes all user input necessary to start the session and then walks away to use colocated retail facilities while they wait), the alternative to a seamless retry could be an EV that is not getting any charge and EVSE that is not available to charge other vehicles until the user happens to return or gets an alert through a mobile application or SMS. The seamless retry mechanism can also provide an improved experience for the end user if there is not an alternative EVSE available for the user to move to upon the first charge attempt failure. In other cases where the user is closely paying attention to the charging session and might have other EVSE to choose from, the additional time taken by seamless retry might cause frustration, especially if it does not ultimately result in a successful charge session. In this case, the potential detriment to the user experience can be mitigated by communicating additional information to end users when implementing seamless retry. Some examples of this information include:

- First attempt has failed, and the system is retrying.
- Number of attempts made.
- Time spent retrying or time since plug-in.
- Specific recommendations based on the type of failure preventing a successful charge session (when possible).
- Specific state of progress on charge setup (e.g., Step 1 of 3).

Implementation-Specific Enhancements for Seamless Retry

Seamless retry can be further enhanced by either side (EV or EVSE) implementing the mechanism with a more discriminating approach. Providing details on these additional enhancements is outside the scope of this document, but doing so is not precluded by this document, and some possibilities are included here for reference.

Additional exit criteria: These are examples of specific types of failures that will lead to a failed charge attempt and after which a seamless retry might be undesirable. These can be used to supplement the required exit criteria defined in [SR-02B-05] and [SR-02C-06]:

- Loss of proximity pilot
- Loss of control pilot
- Loss of protective earth

- Isolation failure
- Overvoltage
- Overcurrent
- Detection of welded contactors
- Reaching a certain number of retries.

Fallback logic: These are examples of parameters that can be adjusted from one charge attempt to the next to increase the chance of achieving a successful charge session.

Table 2. Fallback Examples

Fallback Parameter	Example Failure Trigger
Attempt: Transport Layer Security (TLS) Next attempt: No TLS	Expired certificate Failure to set up TLS
Attempt: ISO 15118-20 Next attempt: ISO 15118-2 Next attempt: DIN SPEC 70121	Protocol-specific sequence error or timeout
Attempt: Plug and Charge (PnC) Next attempt: EIM	Expired Contract Certificate ResponseCode = 'FAILED_*' in the PaymentDetailsRes message

3 Standards and Interoperability

The seamless retry mechanism presented in this document is a recommended practice that currently exists outside of any existing standards. There are, however, interactions with existing standards. These interactions are studied below. In addition, specific recommendations are provided on how to best incorporate this mechanism into existing standards.

3.1 Interactions With Standards

Table 3. Interaction of Proposed Seamless Retry With Existing Standards

Standard	Interaction
ISO 15118-2 Edition 1	Error handling always leads to tearing down of high-level communications (HLC) and resetting state to be prepared for next charging attempt. Allows reestablishing a new V2G communication session (Section 8.8.1) following a "failed" V2G communication session. This approach is compatible with the seamless retry mechanism.
ISO 15118-3 Edition 1	Presents multiple retry mechanisms scoped to specific parts of the signal level attenuation characterization (SLAC) process (i.e., before "matched" state, during matching, after matched state). These retry mechanisms occur within the seamless retry loop and do not conflict. Mentions X1/X2 to E/F and back to X1/X2 transition following data link layer/SLAC errors to retry communication session for either AC or DC charging with HLC (Sections 7.5.1.1 and 7.5.1.2). There is no limiting factor on number of retries or time spent retrying. Does not require power line communication to go to "unmatched" state when triggered by B2 → B1.

Standard	Interaction
DIN SPEC 70121 Revised 2014	Does not present a specific retry mechanism. Does present state machine logic and requirements that enable seamless retry as specified in this document. This approach is compatible with the seamless retry mechanism.
SAE J2847/2 Revision J2847/2_202309	Does not present a specific retry mechanism like DIN SPEC 70121, but the framework and state machine logic described here partially form the seamless retry recommendation in this document. This approach is compatible with the seamless retry mechanism.
IEC 61851-23 Edition 2.0	Describes a pause and reinitiation mechanism where HLC is torn down before being reestablished in a "restart" sequence, which can also be used to restart digital communication after an error condition. Section CC.5.2.3 presents a sequence diagram for EVSE to initiate the restarting of the V2G communication session. This is aligned with the proposed seamless retry recommendation to recover failed sessions and thus poses no incompatibility. Because the "restart" mechanism is aimed toward restarting a "paused" V2G communication session, this document does not limit the number of retry attempts, nor does it set a time limit for retries for the sequence mentioned in this document.
SAE J1772 Revision J1772_202401	Presents a charging session "restart" mechanism where digital communications can be restarted after an error condition, similar to IEC 61851-23. Section 6.5.31.2 describes a sequence diagram for EVSE to initiate the restarting of a failed V2G communication session, which aligns with the proposed seamless retry recommendation and poses no incompatibility. Similar to IEC 61851-23, this document does not impose any constraints on number of retries allowed or an upper time limit after which retries are not allowed.
IEC 61851-1 Edition 3.0	Table A.6 stipulates a minimum time of 3 seconds in case the EVSE realizes a B1 → B2 → B1 → X state transition. In this case, the proposed version of seamless retry defines TT_SR_B1_dwell to be a minimum of 4 seconds, and hence presents no perceived conflict.

3.2 Recommendations to Standards

IEC 61851-23 and SAE J1772 have incorporated the pause and restart mechanism into their state machine logic. Both of these documents mention that this "restart" mechanism can be used for failed sessions in addition to paused sessions. To improve the user experience, a recommendation should be added to notify users when the maximum number of restart attempts has been reached. Secondly, adding a timeout for maximum time spent retrying before notifying users and explicit timers similar to the "dwell" timers (as explained in earlier sections of this document) to the currently defined state machine logic would make restarting from failed V2G sessions more robust.

3.3 Interoperability

As detailed in the Table 3, the seamless retry mechanism proposed in this document poses no interoperability issues with existing standards except for the mechanism presented in ISO 15118-3, where the transition to State E/F and back to X1/X2 is the only way perceived to indicate intent to retry. In contrast, the seamless retry mechanism proposed in this document uses the state transition from X1 to X2 to indicate intent to retry before using States E and F. However, it should be noted that the same incompatibility also exists for the proposed retry mechanism mentioned in IEC 61851-23 and SAE J1772 as given in Table 3. To avoid this conflict, users may transition to State X → E → B1 → B2 or State X → F → B1 → B2 as mentioned in IEC 61851-23 and SAE J1772. However, in this document, we avoid transitions to State E or State F to avoid problems with EV and/or EVSE becoming stuck in unrecoverable error states.

4 Conclusion and Future Work

This work explores the concept of seamless retry within the DC fast charging ecosystem that aims to improve the overall EV charging experience by addressing the issue of charging disruptions. The introduction of this innovative mechanism aims to significantly reduce the inconvenience caused by the typical error resolution process, which often necessitates manual reconnection efforts by the user, which can lead to frustration and a suboptimal user experience. As EV usage continues to grow, the necessity for easy-to-use charging technology becomes increasingly paramount. The seamless retry mechanism, under the constraints of the TT_SR_session timeout, not only ensures operational efficiency, but also exemplifies the potential for intelligent system design in mitigating technical issues without burdening the user.

Future work could improve the proposed seamless retry mechanism by providing case-by-case guidance for detecting and handling specific failure types. Additionally, further investigation is needed to explore new error recovery methods that do not require a complete reset of the communication session. Finally, developing test cases to use with seamless retry implementations would allow a common verification of functionality. Gathering field data to characterize the efficacy of this method would also help to steer further improvements. In summary, future work in this area should focus on developing tighter and targeted retry methods and further maturing the mechanism with additional implementation details and verification test cases.

Appendix A. Application of Seamless Retry in a Real-World Scenario

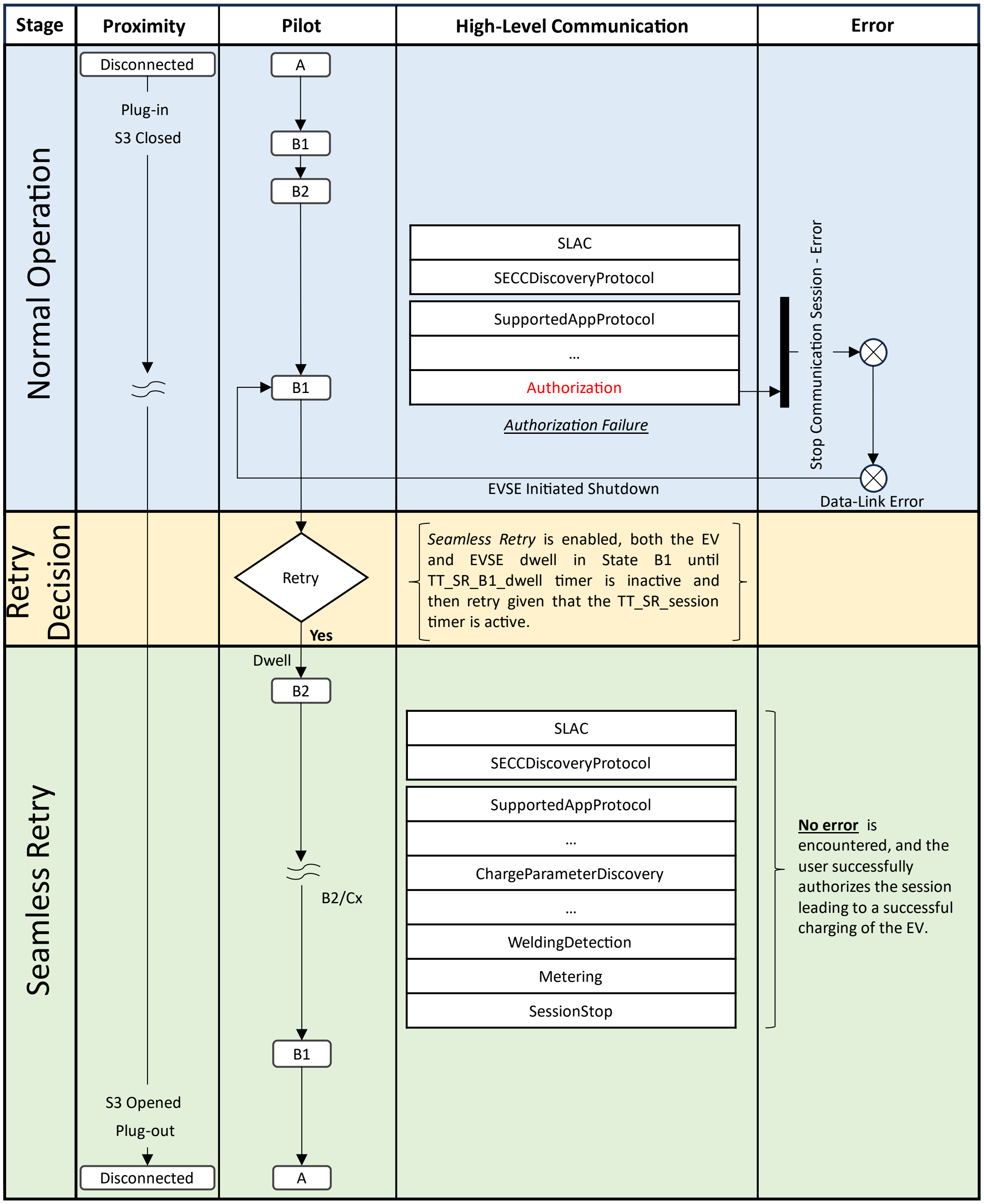

Figure A-1. Application of seamless retry to overcome an authorization error

Figure A-1 considers the application of the seamless retry mechanism in a real-life scenario where an authorization failure interrupts the EV charging procedure. In typical operation, the EV transitions from a disconnected state (State A) as the user plugs in their EV, through initial connection (State B1), to communication of the EVSE's readiness (State B2), where V2G setup and HLC protocols, including authorization, take place. Upon encountering an authorization failure in this scenario, the EVSE initiates a shutdown, returning both the EV and EVSE back to State B1.

In this case, however, seamless retry is implemented on both the EV and EVSE. Therefore, upon transition to State B1, instead of prompting the user to unplug, both the EV and EVSE enter a dwell period in State B1 that allows them to reset all state variables and timers related to the execution of a single charge attempt. After the TT_SR_B1_dwell timer is expired, the EVSE makes a transition back to State B2, reinitiating the V2G session. During this second charge attempt, the user rectifies their authorization issue, and the system proceeds successfully with the charging session (i.e., advances to State Cx for power transfer). Figure A-1 underscores the retry mechanism's capacity to streamline the user experience by automating the error recovery process and avoiding the need for a manual unplug and re-plug.

Appendix B. Control Pilot States

Table B-1. Control Pilot States

State	Description
A	EVSE connected to power source, EV is not connected
B1	EVSE is connected to EV but not ready to supply power
B2	EVSE is connected to the EV and ready to supply power
C	EVSE and EV connected and ready to charge (ventilation not required)
D	EVSE and EV connected and ready to charge (ventilation required)
E	EVSE shut off
F	EVSE unavailable
X1	B1 or C1 or D1
X2	B2 or C2 or D2
Bx	B1 or B2
Cx	C1 or C2
Dx	D1 or D2

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. Funded by the Joint Office of Energy and Transportation, 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.

DOE/GO-102024-6447 • December 2024