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TECHNICAL REPORT

colour inside

OPC unified architecture – Part 2: Security Model

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CONTENTS

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OPC UNIFIED ARCHITECTURE –

Part 2: Security Model

FOREWORD

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IEC TR 62541-2, which is a technical report, has been prepared by subcommittee 65E: Devices and integration in enterprise systems, of IEC technical committee 65: Industrial-process measurement, control and automation.

This third edition cancels and replaces the second edition of IEC TR 62541-2, published in 2016. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) protection-targets definition change;

b) threat type clarifications;

c) expanded best practices;

d) added Websockets;

e) added Pub/Sub.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
65E/679/DTR	65E/703/RVDR

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

Throughout this document and the referenced other Parts of the series, certain document conventions are used:

Italics are used to denote a defined term or definition that appears in the “Terms and definition” clause in one of the parts of the series.

Italics are also used to denote the name of a service input or output parameter or the name of a structure or element of a structure that are usually defined in tables.

The italicized terms and names are also often written in camel-case (the practice of writing compound words or phrases in which the elements are joined without spaces, with each element's initial letter capitalized within the compound). For example, the defined term is AddressSpace instead of Address Space. This makes it easier to understand that there is a single definition for AddressSpace, not separate definitions for Address and Space.

A list of all parts of the IEC 62541 series, published under the general title *OPC Unified Architecture*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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OPC UNIFIED ARCHITECTURE –

Part 2: Security Model

1 Scope

This part of IEC 62541 describes the OPC Unified Architecture (OPC UA) security model. It describes the security threats of the physical, hardware, and software environments in which OPC UA is expected to run. It describes how OPC UA relies upon other standards for security. It provides definition of common security terms that are used in this and other parts of the OPC UA specification. It gives an overview of the security features that are specified in other parts of the OPC UA specification. It references services, mappings, and *Profile*s that are specified normatively in other parts of the OPC UA Specification. It provides suggestions or best practice guidelines on implementing security. Any seeming ambiguity between this part and one of the other normative parts does not remove or reduce the requirement specified in the other normative part.

It is important to understand that there are many different aspects of security that have to be addressed when developing applications. However, since OPC UA specifies a communication protocol, the focus is on securing the data exchanged between applications. This does not mean that an application developer can ignore the other aspects of security like protecting persistent data against tampering. It is important that the developers look into all aspects of security and decide how they can be addressed in the application.

This part is directed to readers who will develop OPC UA *Client* or *Server* applications or implement the OPC UA services layer. It is also for end Users that wish to understand the various security features and functionality provided by OPC UA. It also offers some suggestions that can be applied when deploying systems. These suggestions are generic in nature since the details would depend on the actual implementation of the *OPC UA Application*s and the choices made for the site security.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC TR 62541-1, *OPC Unified Architecture – Part 1: Overview and Concepts*

IEC 62541-4, *OPC Unified Architecture – Part 4: Services*

IEC 62541-5, *OPC Unified Architecture – Part 5: Information Model*

IEC 62541-6, *OPC Unified Architecture – Part 6: Mappings*

IEC 62541-7, *OPC Unified Architecture – Part 7: Profiles*

IEC 62541-12, *OPC Unified Architecture – Part 12: Discovery and Global Services*

IEC 62541-14, *OPC Unified Architecture – Part 14: PubSub*

IEC 62351 (all parts), *Power systems management and associated information exchange*

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TR 62541-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
Access Restriction
limit on the circumstances where an operation, such as a read, write or a call, can be performed on a *Node*

Note 1 to entry: Operations can only be performed on a *Node* if the *Client* has the necessary *Permissions* and has satisfied all of the *Access Restrictions*.

3.1.2
Access Token
digitally signed document that asserts that the subject is entitled to access a *Resource*

Note 1 to entry: The document includes the name of the subject and the *Resource* being accessed.

3.1.3
Application Instance
individual installation of a program running on one computer

Note 1 to entry: There can be several Application Instances of the same application running at the same time on several computers or possibly the same computer.

3.1.4
Application Instance Certificate
Certificate of an individual *Application Instance* that has been installed in an individual host

Note 1 to entry: Different installations of one software product would have different Application Instance Certificates. The use of an *Application Instance Certificate* for uses outside of what is described in the specification could greatly reduce the security provided by the *Application Instance Certificate* and should be discouraged.

3.1.5
Asymmetric Cryptography
Cryptography method that uses a pair of keys, one that is designated the *Private Key* and kept secret, the other called the *Public Key* that is generally made available

Note 1 to entry: Asymmetric Cryptography is also known as "public-key cryptography". In an Asymmetric Encryption algorithm when an entity “A” requires *Confidentiality* for data sent to entity “B”, then entity “A” encrypts the data with a Public Key provided by entity “B”. Only entity “B” has the matching Private Key that is needed to decrypt the data. In an asymmetric Digital Signature algorithm when an entity “A” requires message Integrity or to provide *Authentication* for data sent to entity “B”, entity A uses its Private Key to sign the data. To verify the signature, entity B uses the matching Public Key that entity A has provided. In an asymmetric key agreement algorithm, entity A and entity B each send their own Public Key to the other entity. Then each uses its own Private Key and the other's Public Key to compute the new key value.’ according to IS Glossary.

3.1.6
Asymmetric Encryption
mechanism used by *Asymmetric Cryptography* for encrypting data with the *Public Key* of an entity and for decrypting data with the associated *Private Key*

3.1.7
Asymmetric Signature
mechanism used by *Asymmetric Cryptography* for signing data with the *Private Key* of an entity and for verifying the data's signature with the associated *Public Key*

3.1.8
Auditability
security objective that assures that any actions or activities in a system can be recorded

3.1.9
Auditing
tracking of actions and activities in the system, including security related activities where *Audit* records can be used to review and verify system operations

3.1.10
Authentication
security objective that assures that the identity of an entity such as a *Client*, *Server*, or user can be verified

3.1.11
Authorization
ability to grant access to a system resource

Note 1 to entry: Authorization of access to resources should be based on the need-to-know principle. It is important that access is restricted in a system.

3.1.12
AuthorizationService
Server which validates a request to access a *Resource* and can return an *Access Token* that grants access to the *Resource*

Note 1 to entry: The *AuthorizationService* is also called STS (Security Token Service) in other standards.

3.1.13
Availability
security objective that assures that the system is running normally, that is, no services have been compromised in such a way to become unavailable or severely degraded

3.1.14
Certificate Authority
entity that can issue *Certificate*s, also known as a CA

Note 1 to entry: The *Certificate* certifies the ownership of a Public Key by the named subject of the *Certificate*. This allows others (relying parties) to rely upon signatures or assertions made by the Private Key that corresponds to the *Public Key* that is certified. In this model of trust relationships, a CA is a trusted third party that is trusted by both the subject (owner) of the *Certificate* and the party relying upon the *Certificate*. CAs are characteristic of many Public Key infrastructure (PKI) schemes

3.1.15
CertificateStore
persistent location where *Certificate*s and *Certificate* revocation lists (CRLs) are stored

Note 1 to entry: It may be a disk resident file structure, or, on Windows platforms, it may be a Windows registry location.

3.1.16
Claim
statement in an *Access Token* that asserts information about the subject which the *Authorization Service* knows to be true

Note 1 to entry: Claims can include username, email, and *Roles* granted to the subject.

3.1.17
Confidentiality
security objective that assures the protection of data from being read by unintended parties

3.1.18
Cryptography
transforming clear, meaningful information into an enciphered, unintelligible form using an algorithm and a key

3.1.19
Cyber Security Management System
program designed by an organization to maintain the security of the entire organization's assets to an established level of *Confidentiality*, *Integrity*, and *Availability*, whether they are on the business side or the industrial automation and control systems side of the organization

3.1.20
Digital Signature
value computed with a cryptographic algorithm and appended to data in such a way that any recipient of the data can use the signature to verify the data's origin and *Integrity*

3.1.21
Hash Function
algorithm such as SHA-1 for which it is computationally infeasible to find either a data object that maps to a given hash result (the "one-way" property) or two data objects that map to the same hash result (the "collision-free" property)

Note 1 to entry: See IS Glossary.

3.1.22
Hashed Message Authentication Code
MAC that has been generated using an iterative *Hash Function*

3.1.23
Integrity
security objective that assures that information has not been modified or destroyed in an unauthorized manner

Note 1 to entry: See IS Glossary.

3.1.24
Identity Provider
Server which verifies credentials provided by a *Security Principal* and returns a token which can be passed to an associated *Authorization Service*

3.1.25
Key Exchange Algorithm
protocol used for establishing a secure communication path between two entities in an unsecured environment whereby both entities apply a specific algorithm to securely exchange secret keys that are used for securing the communication between them

Note 1 to entry: A typical example of a Key Exchange Algorithm is the SSL Handshake Protocol specified in SSL/TLS.

3.1.26
Message Authentication Code
short piece of data that results from an algorithm that uses a secret key (see *Symmetric Cryptography*) to hash a *Message* whereby the receiver of the *Message* can check against alteration of the *Message* by computing a *MAC* that should be identical using the same *Message* and secret key

3.1.27
Message Signature
Digital Signature used to ensure the *Integrity* of *Messages* that are sent between two entities

Note 1 to entry: There are several ways to generate and verify Message Signatures; however, they can be categorized as symmetric (See Entry 3.1.40) and asymmetric (See Entry 3.1.5) approaches.

3.1.28
Non-Repudiation
strong and substantial evidence of the identity of the signer of a *Message* and of *Message Integrity*, sufficient to prevent a party from successfully denying the original submission or delivery of the *Message* and the *Integrity* of its contents

3.1.29
Nonce
random number that is used once typically by algorithms that generate security keys

3.1.30
Permission
right to execute an operation, such as a read, write or a call, on a *Node*

3.1.31
Private Key
secret component of a pair of cryptographic keys used for *Asymmetric Cryptography*

Note 1 to entry: Public Key and Private Key are always generated as a pair, if either is updated the other shall also be updated.

3.1.32
Public Key
publicly-disclosed component of a pair of cryptographic keys used for *Asymmetric Cryptography*

Note 1 to entry: See IS Glossary.

Note 2 to entry: *Public Key* and *Private Key* are always generated as a pair, if either is updated the other shall also be updated.

3.1.33
Public Key Infrastructure
set of hardware, software, people, policies, and procedures needed to create, manage, store, distribute, and revoke *Certificates* based on *Asymmetric Cryptography*

Note 1 to entry: The core PKI functions are to register users and issue their public-key *Certificates*, to revoke *Certificates* when required, and to archive data needed to validate *Certificates* at a much later time. Key pairs for data *Confidentiality* may be generated by a *Certificate* authority (CA); it is a good idea to require a *Private Key* owner to generate their own key pair as it improves security because the *Private Key* would never be transmitted according to IS Glossary. See PKI and X509 for more details on *Public Key* Infrastructures.

3.1.34
Resource
secured entity which an application needs to access

Note 1 to entry: A *Resource* is usually a *Server*.

3.1.35
Rivest-Shamir-Adleman
algorithm for *Asymmetric Cryptography*, invented in 1977 by Ron Rivest, Adi Shamir, and Leonard Adleman

Note 1 to entry: See IS Glossary.

3.1.36
Role
function assumed by a *Client* when it accesses a *Server*

Note 1 to entry: A *Role* may refer to a specific job function such as operator or engineer.

3.1.37
Scope
Claim representing a subset of a *Resource*

Note 1 to entry: A *Scope* may indicate a set *Nodes* managed by a *Server*.

3.1.38
Security Key Service
Server that accepts *Access Tokens* issued by the *Authorization Service* and returns security keys that can be used to access the specified *Resource*

Note 1 to entry: The keys are typically used for cryptography operations such as encrypting or decrypting messages sent on a *PubSub* stream.

3.1.39
Secure Channel
in OPC UA, communication path established between an OPC UA *Client* and *Server* that have authenticated each other using certain OPC UA services and for which security parameters have been negotiated and applied

3.1.40
Symmetric Cryptography
branch of cryptography involving algorithms that use the same key for two different steps of the algorithm (such as encryption and decryption, or signature creation and signature verification)

Note 1 to entry: See IS Glossary.

3.1.41
Symmetric Encryption
mechanism used by *Symmetric Cryptography* for encrypting and decrypting data with a cryptographic key shared by two entities

3.1.42
SecurityGroup
publisher and subscribers that utilize a shared security context

3.1.43
Symmetric Signature
mechanism used by *Symmetric Cryptography* for signing data with a cryptographic key shared by two entities

Note 1 to entry: The signature is then validated by generating the signature for the data again and comparing these two signatures. If they are the same, then the signature is valid, otherwise either the key or the data is different from the two entities.

3.1.44
TrustList
list of *Certificate*s that an OPC UA Application has been configured to trust

3.1.45
Transport Layer Security
standard protocol for creating *Secure Channel*s over IP based networks

3.1.46
X.509 Certificate
Certificate in one of the formats defined by X.509 v1, 2, or 3

Note 1 to entry: An *X.509 Certificate* contains a sequence of data items and has a *Digital Signature* computed on that sequence. OPC UA only uses V3.

3.2 Abbreviated terms

AES	Advanced Encryption Standard
CA	Certificate Authority
CRL	Certificate Revocation List
CSMS	Cyber Security Management System
DNS	Domain Name System
DSA	Digital Signature Algorithm
ECDH	Elliptic Curve Diffie-Hellman
ECDSA	Elliptic Curve Digital Signature Algorithm
HMAC	Hash-based Message Authentication Code
JSON	JavaScript Object Notation
JWT	JSON Web Token
NIST	National Institute of Standard and Technology
PKI	Public Key Infrastructure
RSA	Public key algorithm for signing or encryption, Rivest, Shamir, Adleman
SHA	Secure Hash Algorithm (Multiple versions exist SHA1, SHA256,…)
SKS	Security Key Server
SOAP	Simple Object Access Protocol
SSL	Secure Sockets Layer
TLS	Transport Layer Security
UA	Unified Architecture
UACP	Unified Architecture Connection Protocol
UADP	Unified Architecture Datagram Protocol
URI	Uniform Resource Identifier
XML	Extensible Mark-up Language

4 OPC UA security architecture

4.1 OPC UA security environment

OPC UA is a protocol used between components in the operation of an industrial facility at multiple levels: from high-level enterprise management to low-level direct process control of a device. The use of OPC UA for enterprise management involves dealings with customers and suppliers. It may be an attractive target for industrial espionage or sabotage and may also be exposed to threats through untargeted malware, such as worms, circulating on public networks. Disruption of communications at the process control could result in financial losses, affect employee and public safety or cause environmental damage.

OPC UA will be deployed in a diverse range of operational environments with varying assumptions about threats and accessibility, and with a variety of security policies and enforcement regimes. OPC UA, therefore, provides a flexible set of security mechanisms. Figure 1 is a composite that shows a combination of such environments. Some OPC UA *Applications* are on the same host and can be easily protected from external attack. Some OPC UA *Applications* are on different hosts in the same operations network and might be protected