TESTBED-17: DATA CENTRIC SECURITY ER

ENGINEERING REPORT

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ABSTRACT

This OGC Testbed-17 Engineering Report (ER) documents the enhancement of applying Data Centric Security (DCS) to OGC API Features, OGC API Maps (draft), and OGC API Tiles (draft).

As organizations move to the cloud, it is important to incorporate DCS into the design of the new cloud infrastructure, enabling the use of cloud computing, even for sensitive geospatial data sets. The ER documents the applicability of Zero Trust through a Data Centric security approach (DCS) when applied to vector and binary geospatial data sets (Maps, Tiles, GeoPackage containers) and OGC APIs.

The defined architecture extends the typical Zero Trust Domain component by introducing a Key Management System (KMS) to support key registration and the management of access conditions for key retrieval. The prototype implementations (DCS Client, DCS Server and KMS) demonstrate how to request encrypted geospatial data as JSON for encrypted vector data, HTTP Multipart for encrypted map data or GeoPackage with encrypted content; how to obtain decryption key(s) and how to decrypt and display the protected data in a mobile application on Android.

EXECUTIVE SUMMARY

Data Centric Security (DCS) is an approach to apply security directly to data, independent from security features provided by a network, servers or applications. For Data Centric Security in the geospatial domain, proof-of-concept implementations were developed through work in OGC Testbed-15 and Testbed-16. Initially Extensible Markup Language (XML) based standards to label and protect geospatial feature data in Testbed-15 according to the NATO STANAG 4774 and 4778 specifications, the work expanded into JavaScript Object Notation (JSON) based structures during Testbed-16.

For Testbed-17, the primary goal of the DCS task was to apply Data Centric Security in the context of OGC API Standards that enable the delivery of binary data representations such as images and GeoPackage.

The motivation for applying Data Centric Security is the ability to protect sensitive data independently from controlling the access to systems storing and transferring such data. An example of such systems is increasingly popular cloud-based data storage or content delivery platforms. A fundamental requirement is that the data sets are always protected, until an authorized actor makes use of the data. Additional requirements include the need for representation of the source of the information, as well as an assurance that the information has not been tampered with. When looking at drafting OGC Standards such as an OGC API in a Data Centric Security scenario, standards need to include ways to classify the security requirements around data access. Data Centric Security protected data could be stored locally at the client location in order to be used within the validity period of time.
OGC members can derive business value from applying Data Centric Security in the following areas:

- Similarities between the Data Centric Security approach in the geospatial domain and the commercial/enterprise Digital Rights Management (DRM) architecture improves marketing perspectives: Distributing protected geospatial binary content (satellite imagery, sensitive content structured as a GeoPackage container) is similar to DRM.
- Flexible control over the decryption via a fit-for-purpose Key Management System.
- Interoperability through the support for different encoding standards such as XML and JSON. Work in Testbed-17 demonstrated the interoperability for DCS protected binary geospatial data sets and a way to protect and distribute packaged content.
- Leverage a common Zero Trust Domain architecture whereby a common security context is shared by all components based on Bearer Access Tokens as defined in The OAuth 2.0 Authorization Framework: Bearer Token Usage.
- Use GeoPackage with (individually) encrypted data for OGC API — Features or — Tiles that offer flexible decryption of content as necessary. This is an advantage compared to the standard approach of encrypting entire GeoPackage files, as these need to be decrypted as a whole before content can be extracted. The introduced approach allows for example mobile applications to just decrypt those tiles or features that are to be rendered on the display. This saves memory, increases performance and thereby extends battery lifetime.

The Testbed-17 DCS work envelope is defined by the results from Testbed-16 and the ambition to establish DCS for OGC API responses containing binary data. In particular, the following questions were considered:

- How can an implementation of the draft OGC API — Maps specification be used to return an encrypted image of a map request?
- How can an implementation of the OGC API — Features standard be used to return a GeoPackage container that contains encrypted features?
- How can an implementation of the draft OGC API — Tiles specification be used to return a GeoPackage container that contains encrypted tiles?
- Which metadata fields in the response allow a client application to successfully decrypt the "blob" of data?
- How can one be assured that the decryption of the encrypted responses can only be carried out with trusted applications and legitimate users?
- What are the implications of processing encrypted data regarding storage, processing times for encryption and decryption, as well as CPU burden?
The Testbed-17 findings demonstrate the ability to support Data Centric Security applied to binary geospatial data sets. A mobile client application running on the Android operating system was implemented to request and decrypt protected binary content, such as encrypted images (OGC API — Maps (draft)), encrypted features (OGC API — Features) as well as GeoPackages with encrypted content based on OGC API — Features and OGC API — Tiles (draft).

In support of the experimentation in this Testbed, several Technology Integration Experiments (TIEs)/scenarios were defined:

- The first scenario depicted the exchange of DCS-protected content from an OGC API Maps implementation.
- The second scenario depicted the exchange of DCS-protected content from an OGC API Features implementation.
- The third scenario depicted the exchange of DCS-protected GeoPackages containing encrypted features or map tiles requested via implementations of OGC API — Features or OGC API — Tiles.

This ER introduces GeoPackage encryption extensions for storing Features or Tiles in Annex A.

Future OGC Innovation Program activities should extend and implement access control based on spatio-temporal policies to complement the Testbed-17 Data Centric Security architecture towards a Zero Trust Domain architecture. In particular, further activities could demonstrate how to implement the Data Centric Security architecture (including access control) in a Federated Security environment as outlined in OGC Testbed-16: Federated Security. Another future activity should focus on the standardization of a Key Management System API meeting the specific requirements for key management with Data Centric Security enabled geospatial data.

**KEYWORDS**

The following are keywords to be used by search engines and document catalogues.

ogcdoc, OGC document, Data-Centric Security
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SECURITY CONSIDERATIONS

When applying Data Centric Security, a false assumption might be drawn that encryption of data is the compulsory solution to everything. This is not true. Why? It is certainly possible to tamper encrypted data so that it still decrypts, but would produce fraudulent information in the “clear” (after being decrypted). Encryption provides confidentiality, as the encrypted data can only be transformed into the “clear” by applications or users that are in possession of the decryption key (and support for the cipher algorithm in use).

To completely trust encrypted data, assurance about integrity and most likely authenticity must be implemented. Even though the implementation of integrity also relies on encryption, it focuses on encrypting the hash value of the data (either before or after it was encrypted) and not the data itself. Whereas encryption is usually based on a shared secret (as symmetric key), digital signatures require the use of asymmetric keys (a public key shared with all relevant entities and a private key under sole possession of the owning user). Extending integrity to authenticity is quite simple, as it only requires that a certificate is created (by a trusted Certificate Authority) that bundles the public key with the identity information of the entity that owns (and is in single possession of) the associated private key.

Testbeds 15, 16 and 17 have successfully demonstrated how confidentiality can be applied to geospatial data, returned via OGC APIs. The focus was to encrypt responses:

- OGC API Maps for DCS returns a HTTP Multipart response where the second part represents the encrypted binary data of the map image
- OGC API Features for DCS returns a JSON container containing a collection of encrypted features encoded in GeoJSON or a GeoPackage where each feature entry is encrypted
- OGC API Tiles for DCS returns a GeoPackage where each tile data is encrypted

The Testbed 17 result GeoPackage Encryption Extension provides — as the name suggests — an approach to ensure confidentiality of the data stored in a GeoPackage. There is no guarantee about the integrity of the GeoPackage or even its authenticity. To ensure integrity of a GeoPackage, and thereby making it possible to detect tampering, it would be required to calculate the hash value for the entire GeoPackage and then create a digital signature. This digital signature would then have to be stored with some trusted entity, like a Content Delivery Network (CDN), that allows to retrieve the digital signature of a hash value. A similar process is in place for the distribution of binary software packages: JavaScript download with integrity check or Linux package distribution leverages SHA256 or SHA384 hash value verification.
The following organizations submitted this Document to the Open Geospatial Consortium (OGC):

- m-click.aero GmbH
- Secure Dimensions GmbH

All questions regarding this document should be directed to the editor or the contributors:

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1

SCOPE
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This OGC Engineering Report (ER) is deliverable D007 of the OGC Testbed-17 activity (Data Centric Security Across OGC APIs) performed as an OGC Innovation Program activity.

This document expands on the results in the area of geospatial Data Centric Security from OGC Testbed-16 by evaluating options to request binary geospatial data formats via implementations of the draft OGC API — Maps, and OGC API — Tiles, and the approved OGC API — Features standard. In particular, this ER discusses and outlines the approaches for extending the OGC GeoPackage Encoding Standard to support encrypted data (features or map tiles) plus adequate metadata for enabling client applications to perform the integrity checking, decryption and visualization. Regarding the use of image data formats, this ER also describes how the draft OGC API Maps could be extended to return encrypted map images as a HTTP Multipart response.

Another addition in the anticipated usage scenarios (and therefore in TIEs) is that encrypted content delivered as a GeoPackage container remains in the client’s (local) storage and can be decrypted and displayed multiple times. It is also possible to share locally stored GeoPackage content with other users and applications by adopting access conditions to the (decryption) key via the Key Management System.

When it comes to identifying an architecture to solve a particular problem or challenge, it is wise to not start from scratch if working solutions exist. In that sense, the Testbed-17 architecture differs only slightly from the Testbed-16 architecture.
The Testbed-17 DCS architecture consists of the following components:

**Authorization Server (AS)**

This component remains unchanged from Testbed-16: It acts as an OAuth2 / OpenID Connect compliant Authorization Server. The DCS Client application requests access tokens from this component after the user has logged in. The DCS Server and Key Management Server use the Authorization Server’s Token Introspection endpoint to validate access token.

**Identity Management (IdM)**

The Identity Management component supports social login from Facebook, Google and the OGC, as well as approximately 2800 universities. When logging in via the OGC portal IdP, a user's active OGC projects become available as OpenID Connect claim `ogc-is-member-of` which can be used to undertake access control. This component is tightly integrated with the AS component.

**Key Management Server (KMS)**

This component ensures that (de/en)cryption keys can be created, registered and obtained from applications and services by presenting an access token. The KMS also supports the modification of access conditions of registered keys by owning users.
DCS Server

This component is implemented as a plugin to GeoServer v2.20 that supports to request encrypted responses for the OGC’s Maps, Features and Tiles APIs. In order to execute the plugin, the standard OGC APIs must be extended with additional request parameters. On behalf of a user, for each request, the DCS Server generates and registers (de/en)cryption keys with the KMS.

NOTE 1: The DCS Server’s implementation changed from a generic OGC API Proxy to an extension plugin (module) to GeoServer. This tight integration is necessary to accommodate a high performance processing when creating GeoPackage containers with encrypted content.

DCS Client

This component was implemented as an Android mobile application that supports the DCS protocol offered by the DCS Server to request, decrypt and visualize encrypted responses of various encoding, as documented in the TIE section (See Clause 6).

NOTE 2: The DCS Client changed from a QGIS plugin to an Android mobile application.
2

TERMS, DEFINITIONS AND ABBREVIATED TERMS
This document uses the terms defined in OGC Policy Directive 49, which is based on the ISO/IEC Directives, Part 2, Rules for the structure and drafting of International Standards. In particular, the word “shall” (not “must”) is the verb form used to indicate a requirement to be strictly followed to conform to this document and OGC documents do not use the equivalent phrases in the ISO/IEC Directives, Part 2.

This document also uses terms defined in the OGC Standard for Modular specifications (OGC 08-131r3), also known as the 'ModSpec'. The definitions of terms such as standard, specification, requirement, and conformance test are provided in the ModSpec.

For the purposes of this document, the following additional terms and definitions apply.

2.1. Terms and definitions

2.1.1. Access token

A token that can be provided as part of a service request that grants access to the service being invoked on. This is part of the OpenID Connect and OAuth 2.0 specification.

2.1.2. Assertion

Information about a user. This usually pertains to a JWT authentication response that provided identity metadata about an authenticated user.

2.1.3. Authentication

The process of identifying and validating a user.
2.1.4. Authorization

The process of granting access to a user.

2.1.5. Credentials

Credentials are pieces of data used to verify the identity of a user.

2.1.6. Client

Clients are applications that want to request identity information or an access token so that they can securely invoke DCS secured services.

2.1.7. DCAP

Data centric audit and protection, term used by Gartner to describe an approach to information security that combines data security and audit with discovery, classification, policy controls, user and role-based access, and real-time data and user activity monitoring to help automate data security and regulatory compliance.

2.1.8. Identity token

A token that provides identity information about the user. Part of the OpenID Connect specification.

2.1.9. Identity provider

An identity provider (IdP) is a service that can authenticate a user.
2.1.10. Federated identity

Federated identity defines linking and using the identities that a user has across several security domains/realms and their identity providers.

2.1.11. OGC API

The OGC API family of standards is a suite of open standards for Web APIs that offer modular building blocks that make it easy for anyone to publish or consume geospatial data on the web.

2.1.12. Realms

A realm contains a set of users and their attributes (credentials, roles). A user belongs to a realm. Realms are isolated from one another and only manage and authenticate the users that they control.

2.1.13. Roles

Roles identify a type or category of user. Admin, user, manager, and employee are all typical roles that may exist in an organization. Applications often assign access and permissions to specific roles rather than individual users.

2.1.14. Users

Users are entities that are able to log into a system. They can have attributes and have specific roles assigned to them.
2.2. Abbreviated terms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<td>AS</td>
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3

INTRODUCTION
INTRODUCTION

The primary goal of the Testbed-17 Data Centric Security (DCS) task was to apply DCS in the context of OGC API Standards that deliver binary data representations such as images and GeoPackage. The motivation for applying Data Centric Security was the ability to protect sensitive data independently from controlling the access to systems storing and transferring such data.

The following questions were considered in the Testbed-17 Data Centric Security (DCS) task:

- How can an implementation of the draft OGC API — Maps specification be used to return an encrypted image of a map request?
- How can an implementation of the OGC API — Features standard be used to return a GeoPackage container that contains encrypted features?
- How can an implementation of the draft OGC API — Tiles specification be used to return a GeoPackage container that contains encrypted tiles?
- Which metadata fields in the response allow a client application to successfully decrypt the “blob” of data?
- How can one be assured that the decryption of the encrypted responses can only be carried out with trusted applications and legitimate users?
- What are the implications of processing encrypted data regarding storage, processing times for encryption and decryption, as well as CPU burden?
RESULTS
RESULTS

This chapter summarizes the key findings regarding DCS data formats and implications to standardization when applying DCS to OGC APIs and the GeoPackage encoding. It further lists issues and security implications when using the GeoPackage encoding.

4.1. Binary data formats for DCS

Depending on the OGC API Standard, different packaging and response encoding make sense. In particular the OGC API Features does only support one binary response encoding that was tested within this Testbed: GeoPackage. The capabilities of the OGC API Features limit request features for only one collection_id. Therefore, a GeoPackage with encrypted content only contains one DCS related table. However, the GeoPackage Encryption Extension for Features defined in the Annex A does support storing features of different types into different tables. This can be illustrated when requesting a DCS GeoPackage via the WFS 2.0 interface.

NOTE: The use of WFS 2.0 for requesting DCS GeoPackage was not an official part of the work and therefore not included in the TIE.

For the OGC API Features standard, it is possible to apply the DCS data format as an extension to XML and JSON. Both approaches were already implemented and documented during Testbed-16. To summarize, the STANAG 4778 XML encoding is supported where the content is GML encoded and JSON structured responses include JWE representations of GeoJSON encoded Features. Please see OGC Testbed-16: Data Centric Security Engineering Report for more details.

For the OGC API Maps and Tiles draft standards that support the return of binary image data (media type image/*), the data could be encrypted by the DCS Server before returning the response to the client. In this Testbed, the equivalent to DRM online streaming, where the application and server negotiate an encryption key to be used for streaming encrypted content, was not implemented. Instead, the more generic approach was implemented, where the encryption key is managed by a KMS.

In this case, the client must obviously receive information about the DEK, aka key metadata with the encrypted binary data. For conveying the encrypted image data and the DEK metadata for the OGC API Maps, the HTTP Multipart response format is used. More details are illustrated in Figure 4.
4.2. DCS GeoPackage Extension

A GeoPackage is the SQLite container and the OGC GeoPackage Encoding Standard governs the rules and requirements of content stored in a GeoPackage container. The GeoPackage standard defines the schema for a GeoPackage, including table definitions, integrity assertions, format limitations, and content constraints. Defined by the Open Geospatial Consortium (OGC)[2] membership with the backing of the US military[3] and published in 2014, GeoPackage has seen wide support from various government, commercial, and open source organizations.

The GeoPackage standard describes a set of conventions for storing the following within a SQLite database:

- Vector features
- Tile matrix sets of imagery and raster maps at various scales
- Attributes (non-spatial data)
- Extensions

This Testbed-17 Engineering Report defines two GeoPackage extensions to store encrypted data:

- GeoPackage Encryption Extension to store Features
- GeoPackage Encryption Extension to store Tiles

See Annex A for more details.

4.2.1. General Containerized Format

Inspired by previous work using XML structures defined in STANAG 4778 and 4774, previous Testbeds already defined a general containerized format based on JSON encoding: OGC Testbed-16: Data Centric Security Engineering Report.

Testbed-17 continued this response format for the OGC API Features via the media type application/dcs+geo.

4.3. Implications for OGC API Standardization

Development and Implementation

For applying the concepts of Data Centric Security as a building block to OGC (Features, Maps, Tiles, etc.) APIs being able to easily extend the protocol with additional parameters is important.
Of related importance is that implementations of OGC APIs — that have potential wider use beyond just the “traditional” GIS Community — support flexible processing of additional request parameters and support returning “custom” response formats.

When applying DCS relevant parameters to the OGC APIs leveraging a POST request (www-url-form-encoded) as a secure alternative for the HTTP GET must be possible. This is in particular important if Bearer Access Tokens cannot be added to the HTTP Authorization Header or, when a user requests encrypted content but does not want to disclose the “layers” or “feature types” within the HTTP GET request!

---

**IMPORTANT**
OGC APIs and their implementations must support the declaration and processing of extensions that define new building block with specific request parameters.

**IMPORTANT**
OGC APIs and their implementations must support a security building block classed “HTTP Bearer Token” ([RFC 6750](https://tools.ietf.org/html/rfc6750)).

**IMPORTANT**
OGC APIs and their implementations must support HTTP POST as a secured alternative to HTTP GET. This is in particular important when sending sensitive parameters to the server.

---

### 4.4. Discovered Issues with GeoPackage as response format

When applying encryption to data, the processing burden must obviously be considered. When extending APIs (such as the OGC APIs) that are designed to quickly return short to medium size responses (up to some MBs), the potentially large size, as well as long time required to DCS-protect returning GeoPackage container can turn out to become a kind of Denial-Of-Service attack.

Most OGC API Standards define synchronous RESTful web services, which means that the service returns a HTTP 200 OK success status and the response on the same socket pair as the one used to receive the request. This interaction pattern is acceptable, if the requested response format is streaming-ready. A streaming-ready response format is ZIP. The server can open a Zipped output stream and start immediately to push data down to the client. In the case of GeoPackage, this is not possible as a GeoPackage container is a binary file format that must first be completely created (on the server’s storage) before the stream towards the client can start.
For large GeoPackages, or for those where the creation takes a long time due to encryption, different issues may arise:

- The user client might disconnect from the socket after the TCP standard timeout. The DCS client was not aware of the requirement to set an extra-long (endless) timeout before making the request. Unfortunately, the service — meanwhile creating the GeoPackage — remains unaware of client disconnection, finishes package generation and eventually starts an attempt to deliver the data to the client. Therefore, the service might generate a large GeoPackage and waste CPU and memory by processing a request for which there is no longer a receiver.

- The creation of the (temporary) GeoPackage on the Server produces no space left on device error. In this case, the user would receive an error but most likely retry. This is a dangerous situation, as the server’s storage might become spammed with long running GeoPackage processing tasks, which were started on behalf of perhaps disconnected clients.

- Inattentive or malicious users might produce a sequence of requests by click — cancel — repeat. The issue arises that all requests but the last are lost, as the cancel most likely disconnected the TCP socket.

These situations can quickly turn into a denial-of-service (DoS) attack, if resource quotas that limit resource consumption (per service request) aren’t put in place.

In this testbed, the participants created GeoPackage sizes of 12GB for the default GeoServer data set (Tiger Roads) when requesting TileMatrixSet 0-21. The processing time on a medium size server took approximately 6 hours to create the container. Without a resource quota, the server resources are quickly not available.

A possible solution for problems mentioned above would be to utilize an asynchronous service design allowing clients to submit a GeoPackage processing request, disconnect and wait for the service to generate the required package (a long time running backend task). In order to prevent multiple service calls caused by malicious or unintentional repeated data requests, clients should further be limited on how many of such tasks they are allowed to submit at a time. Finally, The OGC API — Processes standard may fit right to implement such interaction in an OGC compliant way. OGC API — Processes defines an API that supports both synchronous and asynchronous execution of computing processes (and the retrieval of metadata describing their purpose and functionality).
5

IMPLEMENTATION
ASPECTS
The Testbed-17 DCS architecture extends the Testbed 15 and 16 architectures by supporting encryption of binary responses for the OGC API Features, Maps (draft), and Tiles (draft) standards. This feature is implemented in the DCS Server. The DCS client is a mobile application running on Android.

**NOTE:** The aim of this section is to provide a detailed Overview about all aspects of design and component development.

### 5.1. Architecture Overview

The overall architecture supporting the DCS goal is very similar to the one from Testbed-16 (see OGC Testbed-16: Data Centric Security Engineering Report for more details). The following figure illustrates the overall architecture.

![Figure 2 — Testbed-17 Architecture](image)
The Testbed-17 DCS architecture is inspired by the Zero Trust definition as outlined in the OGC Testbed-16: Federated Security Engineering Report: Each request to a DCS enriched OGC API and the KMS requires authentication. This is achieved through the DCS Client that requires an acting user to login first. This results in a Bearer Access Token that the DCS Client requests from the AS. The Bearer Access Token must be used for all requests to the DCS Server and the Key Management Server. Based on the user’s identity that is linked to the Access Token, the DCS Server and KMS apply access control based on the user’s access rights.

Before making a request to the DCS Server, the user has to provide a PIN or secret to the DCS Client. This PIN is added to the request and used as a proof of ownership to the Data Encryption Key (DEK), generated by the DCS Server. The PIN is required to manage the access conditions for the DEK with the KMS at a later stage. Upon a successful request, the DCS Server returns the DCS specific response. In all cases, the encrypted data in the response is based on a cipher key that was created by the DCS Server and registered with the KMS. Therefore, to decrypt the response, the client first parses the response to find the DEK metadata; in particular the kid (key identifier) and the kurl the URL to fetch the key from the KMS. Depending on the actual response format, this information is at different places but is always in a standardized format, leveraging the JSON Web Key specification (RFC 7517). Before undertaking the actual decryption of the response, the client interacts with the KMS and fetches the DEK. In case the KMS returns “forbidden”, the acting user should verify the access conditions for the key, in particular the expiration time. Amendment to the conditions and in particular to the expiration time can be done via the KMS admin pages. To change the access conditions for a DEK, the user has to provide the PIN.

**Figure 3 — Testbed-17 DCS Architecture Interactions Overview**

As illustrated in Figure 3, the interactions can be categorized as follows:

**Category (A)**

Interactions from the client to the server are based on an extension to the parameters defined for the OGC APIs:

- `access_token` parameter (mandatory) contains the value of the Bearer Access Token
- `key_challenge` parameter (mandatory) that contains the (hashed) PIN
• key_challenge_method parameter (mandatory) is either plain or S256. When using S256, the value of the key_challenge must be hashed according to Proof Key for Code Exchange by OAuth Public Clients, Sect. 4.2.

Responses from the server to the client contain the encrypted data.

Category (B)

The server interacts with the KMS to register the DEK that was generated to encrypt the content for the current request.

The response from the KMS contains the DEK identifier (kid).

Category (C)

Interactions between the client and the KMS to fetch a DEK for decrypting the actual response from the server or a GeoPackage that was loaded from (local) storage. The request parameters are

• access_token (mandatory) as defined above
• kid (mandatory) as part of the path (/dek/{kid})
• kek_kid (optional) contains the key identifier for a registered public key that is to be used by the KMS to return the DEK encrypted

The response from the KMS to the client is the JWK encoding of the DEK, including the key’s secret. When the request contains the kek_kid parameter, the response is a JWE where the payload is the JWK encoding of the key. (The referenced public key is used for key wrapping)

Category (D)

In case that the client wants to request encrypted key material defined by interactions of category (C), the client can use the KMS KEK (Key Encryption Key) API to register a public key in JWK format. The key identifier received in the response can be used as illustrated above in category (C).

5.2. DCS Server

The DCS Server implementation by Secure Dimensions is realized as a GeoServer Plugin, available from Github: GeoServer DCS Plugin. For the OGC Testbed-17 initiative, the implementation demonstrates the ability to apply Data Centric Security to geospatial data, requested via implementations of the OGC’s Features, Tiles (draft) and Maps (draft) APIs. In order to support the DCS feature, the OGC API requests are extended with additional query parameters:

• access_token (mandatory) as defined above
- kid (mandatory) as part of the path (/dek/{kid})
- kek_kid (optional) contains the key identifier for a registered public key that is to be used by the KMS to return the DEK encrypted

The request parameter \( f \) determines the response format based on DCS specific media types, valid in the context of this Testbed. The DCS Server implementation supports different response formats specific to an OGC API. The response format for OGC API Maps is a HTTP Multipart response where the first part contains the key metadata in JSON encoding and the encrypted image is an octet-stream provided as part two. For the OGC API — Features standard, two different response formats are supported: (i) encrypted features in JSON container and (ii) GeoPackage container holding encrypted features. For the OGC API — Tiles draft specification, only GeoPackages holding encrypted tiles are supported.

<table>
<thead>
<tr>
<th>OGC-API</th>
<th>DCS MEDIA TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Features</td>
<td>application/dcs+geo</td>
<td>DCS container structure encrypted features, metadata as JSON</td>
</tr>
<tr>
<td>Features</td>
<td>application/dcs+geo;profile=metaSign</td>
<td>DCS container structure encrypted features, metadata as JWS</td>
</tr>
<tr>
<td>Features</td>
<td>application/dcs+geo;profile=metaEncrypt</td>
<td>DCS container structure encrypted features, metadata as JWE</td>
</tr>
<tr>
<td>Features</td>
<td>application/gpkg+dcs</td>
<td>GeoPackage with encrypted features</td>
</tr>
<tr>
<td>Tiles</td>
<td>application/gpkg+dcs</td>
<td>GeoPackage with encrypted tiled coverages</td>
</tr>
<tr>
<td>Maps</td>
<td>application/dcs+{png,jpeg,...}</td>
<td>Multipart response with encrypted map tiles</td>
</tr>
</tbody>
</table>

The actual GeoPackage extensions for encrypted Tiles and Features are described in section “GeoPackage Data Centric Security Extensions” (Annex A).
5.2.1. OGC API Maps Response Format

The OGC API Maps implementation returns an image in the format requested. Typical formats are PNG or JPEG. The DCS response format can be requested via the f parameter using the DCS specific media type `application/dcs+<image format>`.

The structure of the response as a HTTP Multipart is illustrated in the following figure.

- DCS response is multipart/encrypted
  - Part 1: application/json; JSON encoded metadata
  - Part 2: application/octet-stream; binary of encrypted data (AES encryption with CBC does not increase the data volume) *: Occasionally adds a few bytes due to padding + 16bytes for the IV

As illustrated in Figure 4, the response uses content type multipart/encrypted; protocol=application/json. This is a standard way to 'alert' the client about the encodings of the different parts. The response header further contains the boundary identifier of the multipart message (f92d9092-6cb0-4be0-a4b3-16fc71be9d63 in the example above).

The following is an example first part:

```json
{
    "metadata": {
        "originator_confidentiality_label": {
            "confidentiality_information": {
                "policy_identifier": "TB17",
                "classification": "Confidential"
            }
        }
    }
}
```
"data_producer": {
  "origin": "Not NGA",
  "date": "2021-10-01T14:03:08.409Z"
},
"data_description": {
  "type": "Feature",
  "properties": {
    "name": "tiger:tiger_roads",
    "content_type": "application/geo+json"
  },
  "geometry": {
    "type": "Polygon",
    "coordinates": [
      [-74.02722, 40.684221],
      [-73.907005, 40.684221],
      [-73.907005, 40.878178],
      [-74.02722, 40.878178],
      [-74.02722, 40.684221]
    ]
  }
},
"dek_info": "eyJqa3UiOiJodHRwczpcL1wvb2djLnNLY3VvZS1kaW1lbNpb25zLmNvbVvZWGNzXC8ud2VsbC1rbm93blwv
eyJzdWIiOiJodHRwczpcL1wvb2djLnNLY3VvZS1kaW1lbNpb25zLmNvbVvZWGNzXC8ud2VsbC1rbm93blwv
eyJzdWIiOiJodHRwczpcL1wvb2djLnNLY3VvZS1kaW1lbNpb25zLmNvbVvZWGNzXC8ud2VsbC1rbm93blwv
eyJzdWIiOiJodHRwczpcL1wvb2djLnNLY3VvZS1kaW1lbNpb25zLmNvbVvZWGNzXC8ud2VsbC1rbm93blwv
eyJzdWIiOiJodHRwczpcL1wvb2djLnNLY3VvZS1kaW1lbNpb25zLmNvbVvZWGNzXC8ud2VsbC1rbm93blwv
"}

Part 1 of the Multipart response

In clear JSON encoding, the client can determine information about the confidentiality labelling, the data producer and the actual data structure. In particular, the boundary of the map images is presented which allows a GIS client to associate the image with the correct location on the rendered display.

For decryption, the client must use the information from the dek_info element. This is a JWT in compact decoding. After decoding, the following information becomes available:
Header of the JWT defining the public key used for signature

```
{
  "jku": "https://ogc.secure-dimensions.com/dcs/.well-known/jwks.json",
  "kid": "Dr. No",
  "alg": "RS256"
}
```

Payload of the JWT describing the key's metadata

Important information for the client is the `kid` or the `kurl` which can be used to fetch the actual decryption key from the KMS. The elements `sub` and `aud` can be used to verify that the key is actually designated to the acting user (identified by the `sub`) and the application itself (identified by the `aud`). Additional information when the key was created (`iat`) by whom (`iss`) and expiration (`exp`) can be used to test applicability and fitness of the key.

The actual key that corresponds to the `kid = 15517e95-c764-4602-9e09-7aad104d480` is illustrated in the following code listing:

```
{
  "kid": "15517e95-c764-4602-9e09-7aad104d480",
  "alg": "A128GCM",
  "kty": "oct",
  "k": "4rE7puBVzdMeXpv1Z3eyHQ",
  "issuer": "4bf1cb21-9ff7-f443-f736-70781d89d413",
  "expires": 1633098786,
  "issued_at": 1633096988,
  "aud": "019b7173-a9ed-7d9a-70d3-9502ad7c0575",
  "sub": "95d3827d-efef-3052-a2df-46d1c7ce77a5"
}
```

Decryption Key in JWK encoding

5.2.2. OGC API — Features JSON Container

The OGC API — Features service implementation returns a JSON encoded container with encrypted features plus relevant metadata. Different format values trigger different encoding for the metadata; the data is always encrypted. All response structures are described in the Data Centric Security ER from Testbed 16.
For a response including digitally signed metadata, the f parameter must be set to application/dcs+geo.
For a response including digitally signed metadata, the f parameter must be set to application/dcs+geo;profile=meta-sign.
For a response including digitally signed metadata, the $f$ parameter must be set to application/dcs+geo;profile=metaEncrypt. The DCS server returns the encrypted metadata as JWE when the request includes the $kek_kid$ which refers to the public key of the user, registered with the KMS. The DCS Server uses that public key to encrypt the cipher key used to encrypt the metadata. This is visible from the JWE header:

```
{
  "cty": "JWS",
  "alg": "RSA-OAEP-256"
}
```

Figure 7 — OGC API Features returning encrypted features collection with metadata as JWE

5.2.3. OGC API — Features GeoPackage Response

The OGC API — Features GeoPackage implementation returns a GeoPackage with encrypted features as described in Annex A.1. This response type can be requested via the $f$ parameter set to application/gpkg+dcs.
5.2.4. OGC API — Tiles GeoPackage Response

The OGC API — Tiles implementation returns a GeoPackage with encrypted tiles as described in Annex A.2. This response type can be requested via the \( f \) parameter set to application/gpkg+dcs.

5.3. DCS Client

The DCS Client implementation for the OGC Testbed 17 demonstrates the ability to request and ingest encrypted geospatial content using OGC APIs.

The actual Compusult implementation is realized using the Compusult GO Mobile Android application, which provides a standards-based geospatial and mapping solution for data discovery and visualization.

- Supports Android 5.0 (API Level 21) and above
- Supports many approved and draft OGC API standards (Maps, Tiles, Features, Styles, Images)
- Supports GeoPackage 1.3.0 and below
- Supports OpenID based authentication
- Supports The Key Management System (KMS) operations
• Supports decoding, verifying and decrypting JOSE and JWT content using Nimbus JOSE + JWT and Bouncy Castle
• Supports decoding and decrypting multi-part binary content using JCA and apache-mim4j

5.3.1. Client Registration

The DCS Client must first register its application with the AUTHENIX service to access the OGC APIs and KMS services. A global private/public key pair is created on the first load of the application and stored in the database for future client requests and decryption.

The client performs a registration request https://www.authenix.eu/oauth/register with the request body below.

```json
{
    "redirect_uris": [
        "http://www.gomobile_dcs.com/oauth2redirect"
    ],
    "grant_types": [
        "authorization_code",
        "refresh_token"
    ],
    "response_types": [
        "code",
        "id_token",
        "code id_token"
    ],
    "client_name": "Compusult DCS Application - Mobile",
    "logo_uri": "https://www.compusult.com/image/layout_set_logo?img_id=12133&t=1615550967456",
    "scope": "openid profile offline_access",
    "contacts": [
        "aparsons@compusult.net"
    ],
    "tos_uri": "http://127.0.0.1:4711/TermsOfUse.php",
    "policy_uri": "http://127.0.0.1:4711/PrivacyStatement.php",
    "software_id": "4ef5dcd6-22a7-4947-a636-4a46a1cf8d43",
    "software_version": "1.0",
    "post_logout_redirect_uris": [
        "https://www.example.com/oauth2logout"
    ]
}
```

The server responds with a registration response including the client_id required for authorization. See below for an example of the server response.

```json
{
    "client_id": "8d90bc42-4401-5f2a-9054-cb407a876ad8",
    "client_id_issued_at": 1629899374,
    "client_name": "Compusult DCS Application - Mobile",
    "client_secret": "...",
    "client_secret_expires_at": 1629928174,
    "contacts": [
        "aparsons@compusult.net"
    ],
    "grant_types": [
        "authorization_code",
        "refresh_token"
    ]
}
```
"refresh_token",
"jwks": null,
"post_logout_redirect_uris": [
  "https://www.example.com/oauth2logout"
],
"redirect_uris": [
  "http://www.gomobile_dcs.com/oauth2redirect"
],
"response_types": [
  "code",
  "id_token",
  "code id_token"
],
"scope": "openid profile offline_access",
"token_endpoint_auth_method": "client_secret_basic"
}

5.3.2. Client Authorization

The DCS client will require the user to authorize against any services that are known to contain Data Centric Security content. For OGC APIs compatible services this is determined by inspecting the format types available for request. For GeoPackages this is determined by checking the registered extensions. If a service/geopackage is determined to require authentication, a user is required to login.

![Figure 10 — DCS Client — Authentication](image)

Before authenticating the user is required to select the server they wish to authenticate against. The OpenID configuration is parsed and used to determine how to construct the appropriate authorization and token requests.

![Figure 11 — DCS Client — Server Selection](image)

After selecting the server, the user provides an authorization request including the registered client_id as well as the user specified code_challenge. An example authorization request will take the form of:

The Client is then asked to select a provider, and provide credentials to authorize the user.

![Figure 12 — DCS Client — Provider Selection](image)

After providing the credentials an authorization response is returned containing the authorization code.

```url
http://www.gomobile_dcs.com/oauth2redirect?code=bdc1634dddb2dd592327da3537064781948fd4ef0&state=xyz&id_token=eyJ0eXAiOiJKV1QiLCJhbGciOiJSUzI1NiIsImtpZCI6IkFTUHVibGljS2V5In0.eyJpc3MiOiJodHRwczpcL1wvd3d3LmF1dGhlbml4LmV1liic3ViljoiYzBmYjJZWEtMTg1Ni0zNjczLgpwZmMgV44NNYQmdT9FU6XweweczqfTbA3Pud_oRzFvI9cxnCyzQ5Kx5K7-utnJ5AdmsCztrkuWyjz3nT9p6PfkywL9akdst58qSjSfNFeNhHEhHf3GUUm3vBNXhT7uxzhrm5vycdGnHx2bLej_Awkw-wRLncGyWGBn_kRJdePncYO78kBK3A4beclMGXkX8VDTO2Xx3usmmEx7Niam9RIN2s4PnGpgtYfGw5dX1qy2n5PFphD2dJbgoCsqqcflCs0arKtRZepSE4pAwbmz4hKDn1rRCnlsNzsw3nOmNrlbXGkCZfROP0zLRWq4J5rORX6uCFxfzyBhIPw
```

The authorization redirect URL is handled by the app, and prompts the user to allow the application to ingest the response. Note the user is asked to select the appropriate app one time, and all subsequent requests afterwards are automatically redirected.
After selecting the app to handle redirection, the application retrieves the authorization code and uses this code to retrieve a valid token for use for the following url: https://www.authenix.eu/oauth/token. Basic Auth request headers are added to the request using the client_secret supplied by the user.

code=bdc1634dddb2dd598327da3537064781948fd4ef0&grant_type=authorization_code&redirect_uri=http%3A%2F%2Fwww.gomobile_dcs.com%2Foauth2redirect&code_verifier=Hlp9DyvxEm0XPxnsb3Mjuut77nI7oHw057nEuajxSmWgdKBqekV68Ydq-lEd2tk_htpdj67u2otTShpws20sw

The server responds with a valid token response. The response contains the access_token required to be used with the KMS and OGC APIs.

```json
{  "access_token": "741e31abc7c6ec5444036b94fca79796b0925e09",  "expires_in": 1800,  "token_type": "bearer",  "scope": "openid profile offline_access",  "refresh_token": "c0ea4ca04432f47af9777374a94dc8dc6e8b41f31"
}
```

If the request was successful, the client is then re-directed and updates the Authorization button to indicate authorization has been successful and that the client can now be used to request Data Centric Security content.

5.3.3. OGC APIs

The DCS client supports ingesting and requesting OGC API services including Tiles, Maps, Features, Styles and Images. Given an OpenAPI definition file the client auto-detects the capabilities of the server and provides the user with options to change formats and styles, as
well as downloading GeoPackage content on a service and layer level. For this testbed the following services were utilized:

- OGC API — Features
- OGC API — Maps
- OGC API — Tiles

5.3.3.1. OGC API — Features

The DCS client reads the OpenAPI definition for an OGC API — Features service and through successive calls to /collections/{collectionId} produces a service with all of its required metadata for requesting content, including available styles and formats.

![Figure 15 — DCS Client for OGC API — Features implementation](image)

To request Data Centric Security content a user must select one of the available DCS formats. After selecting one of the appropriate formats, the client ensures the user is authorized and adds the appropriate request parameters/headers to request the encrypted content.
After receiving the content the client determines the data content-type by decoding and decrypting the data_description.

```
"data_description": eyJqa3UiOiJodHRwczpcL1wvb2djLnNLY3VyZS1kaW1ibnb25zLmNvbVwvZGNzXC8ud2VsbC1rbm93blwvaneyJ0eXBlIjoiRHIuIE5vIiwia2lkIjoiRHIuIE5vIiwia2lkIjoiRHIuIE5vIiwiYWxnIjoiUlMyNTYifQ.
```

After decoding the content, the header is used to retrieve the JWK and decrypt the content.

```
{
  "jku": "https://ogc.secure-dimensions.com/dcs/.well-known/jwks.json",
  "kid": "Dr. No",
  "alg": "RS256"
}
```

The result is a GeoJSON feature which describes the features extents, content-type and other application specific metadata.

```
{
  "type": "Feature",
  "properties": {
    "name": "poly_landmarks",
    "namespace": "http://www.census.gov",
    "content_type": "application/geo+json"
  }
}
```
"geometry": {  
  "type": "MultiPolygon",
  "coordinates": [
    [
      [
        40.87822,
        -73.926377
      ],
      [
        40.87042,
        -73.932477
      ],
      [
        40.874699,
        -73.938081
      ],
      [
        40.882078,
        -73.933406
      ],
      [
        40.87901,
        -73.924598
      ],
      [
        40.878978,
        -73.924506
      ],
      [
        40.87822,
        -73.926377
      ]
    ]
  ]
}

After determining the content-type of the encrypted content a similar approach is taken to decrypt the data in the response. Here the header contains a KMS request that allows the user to reach out to the KMS service and retrieves the appropriate key given the user credentials.

```
{
  "iss": "https:\/\/ogc.secure-dimensions.com",
  "cty": "application\/geo+json",
  "alg": "RS256",
  "jku": "https:\/\/ogc.secure-dimensions.com\/dcs\/.well-known\/jwks.json"
}
```

After the decryption the client converts the GeoJSON features and renders the content on the map.
5.3.3.1.1. GeoPackage from OGC API — Features

The DCS client checks the available formats from the OGC API — Features service and determines if it supports requesting encrypted GeoPackages. If it finds the format of application/dcs+gpk, an option is made available for the user to download a GeoPackage.

```json
{
  "href": "https://ogc.secure-dimensions.com/geoserver/ogc/features/
  collections/tiger:giant_polygon/items?f=application%2Fgpk%2Bdcs",
  "rel": "items",
  "type": "application/gpkg+dcs",
  "title": "tiger:giant_polygon items as application/gpkg+dcs"
}
```
Once downloaded the GeoPackage metadata is read from `gpkg_contents` and the GeoPackage service is generated. The `gpkg_extensions` table is then read to determine if the GeoPackage is a Data Centric Security compliant Feature GeoPackage based on the extension_name `sd_dcs_features`. The encrypted format of the content can also be determined by reading the `gpkg_data_columns` table. See the GeoPackage DCS Features Extension for more details.

The client then requests the feature content based on the map extents like any other GeoPackage Simple Feature layer. The `structure` column must first be decrypted to determine the content-type and the extents of the feature along with other metadata.
The client then requests the encryption key from KMS using the information available in the header.

```
{
  "kid": "730b1bd8-1414-46f0-8dc3-6713f7e86af8",
  "cty": "JWE",
  "enc": "A256GCM",
  "alg": "RSA-OAEP-256"
}
```

After retrieving the key, the structure is decrypted and verified to ensure the user has permission to consume the content. Using the `content_type` property the client determines what type of data to inspect in the encrypted data column.

```
{
  "type": "Feature",
  "properties": {
    "name": "DCSD6E1C05C8A81C2AE74C7AEDEA5EC92C1",
    "namespace": "tiger",
    "namespace_uri": "http://www.census.gov",
    "content_type": "application/geo+json",
    "attributes": [
      "the_geom",
      "NAME",
      "THUMBNAIL",
      "MAINPAGE"
    ],
    "geometry": {
      "type": "Polygon",
      "coordinates": [
        [
          40.70754684,
          -74.02021023
        ]
      ]
    }
  }
}
```
A similar process is followed to decode, decrypt and verify the data content containing the GeoJSON features. After decrypting the content, the GeoJSON is rendered on the map.

```json
{
    "type": "Feature",
    "geometry": {
        "type": "Point",
        "coordinates": [
            40.7075,
            -74.0108
        ]
    },
    "properties": {
        "NAME": "stock",
        "THUMBNAIL": "pics/22037829-Ti.jpg",
        "MAINPAGE": "pics/22037829-L.jpg"
    },
    "id": "poi.2"
}
```
5.3.3.2. OGC API — Maps

The DCS client reads the OpenAPI definition for an OGC API Maps service and through successive calls to /collections/{collectionId} and /collections/{collectionId}/styles produces a service with all of its required metadata for requesting content, including available styles and formats.
To request Data Centric Security content a user must select one of the available DCS formats. After selecting one of the appropriate formats, the client ensures the user is authorized and adds the appropriate request parameters/headers to request the encrypted content.
After receiving the content the client decodes and decrypts multi-part binary content based on its format type. External keys are retrieved from the KMS. These along with the applications stored private key are used to decrypt the content and metadata and display the images on the map.
Figure 23 — DCS Client – OGC API Maps – Manhattan (NY) Roads/Landmarks

5.3.4. OGC API Tiles — GeoPackage

The DCS client checks the available formats from the OGC API — Tiles service and determines if it supports requesting encrypted GeoPackages. If it finds the format tilematrixset-dcs or tilematrix-dcs an option is made available for the user to download a GeoPackage.

```
{
  "rel": "tilematrixset-dcs",
  "type": "image/png",
  "title": "tiger:giant_polygon tile matrix set as DCS GeoPackage"
},
{
  "rel": "tilematrix-dcs",
  "type": "image/png",
  "title": "tiger:giant_polygon tile matrix {tileMatrix} as DCS GeoPackage"
}
```
After selecting the layer to download and choosing to download a GeoPackage the client generates a request using the users access token and selected format type and projection.

https://ogc.secure-dimensions.com/geoserver/ogc/tiles/collections/tiger:poi/map/poi/tiles/EPGS:4326?f-tile=image/png&f=application/gpkg%2Bdcs&multiTileType=tiles&key_challenge=secret&key_challenge_method=plain&access_token=998abda1e387e99003c8a9ff5a314d1a51381b72&kek_kid=730b1bd8-1414-46f0-8dc3-6713f7e86af8

Once downloaded, the GeoPackage metadata is read from gpkg_contents and the GeoPackage service is generated. The gpkg_extensions table is then read to determine if the GeoPackage is a Data Centric Security compliant Feature GeoPackage based on the extension_name sd_dcs_tiles. The encrypted format of the content can also be determined by reading the gpkg_data_columns table. See the GeoPackage DCS Tiles Extension for more details.
The client then requests the feature content based on the map extents like any other GeoPackage Tiled layer. The result is encoded metadata `dcs_info`, encrypted key information `dek_info` and the encrypted tiled images `tile_data`.

First `dcs_info` is decoded, and the header is used to retrieve the key. The parameter `jku` is used to retrieve the `keyset` and load it.

```json
{
  "keys": [
    {
      "kty": "RSA",
      "e": "AQAB",
      "use": "sig",
      "kid": "Dr. No",
      "n": "kHGuPCeY4adIpMu7H5h03eADv1_Tc12zF3LavpAhkC8xXbgDxMkIfNzuV_jcg54crbJGfqnS1eznJjAE3e1kwZOTKPiqGqrL-6DgF/JLgdh8jT95z1Q5MIO7u9-Ru-YR-DxQzYN9Pq3lee8VmaRSRIIClv9i308m2GwUvIlerac2WQ04x84Bf7uNuiDoQEAHupPK6awUsiISwd31Nv6b4pt5j0of46j3jM_YbDdIly1q0vufGQgB_C5yndIQA2odcY2_rVEayqKFBu2V9Smtw"
    }
  ]
}
```

The key defined in the header is then used from the response to decode the JWT content.

```json
{
  "originator_confidentiality_label": {
    "confidentiality_information": {
      "policy_identifier": "TB17",
      "classification": "Top Secret"
    }
  },
  "data_producer": {
    "origin": "Not NGA",
    "date": "2021-08-25T18:38:23.957Z"
  },
  "tile_information": {
    "zoom_level": 14,
    "tile_column": 9647,
    "tile_row": 4486
  },
  "data_information": {
    "hash_alg": "SHA-384",
    "hash_value": "c5c48da9f073c0a0e477d5d7bced25c81e5dc0258b670d9450b33f96275a9f66fea6c81b1ef3475695144e"
  }
}
```
A similar process is followed to decode the JWS dek_info using the key defined in the header to decode the payload resulting in the decryption key required for the data.

```
{
  "sub": "c0fb2eea-1856-3673-80fc-79d0e1efdfdb",
  "aud": "8d90bc42-4401-5f2a-9054-cb407a876ad8",
  "kurl": "https:\/\/ogc.secure-dimensions.com\/kms\/keys\/c2e5dc56-b14b-4f28-8e72-a78779271744",
  "kid": "c2e5dc56-b14b-4f28-8e72-a78779271744",
  "iss": "https:\/\/ogc.secure-dimensions.com",
  "exp": 1629918,
  "alg": "A256GCM",
  "iat": 1629916703949
}
```

The decryption key is then used in conjunction with the Java Cryptography Architecture framework to decrypt the image. The first 16 bytes are read from the data column and used as the IvParameterSpec input to the cipher. The result are decrypted tiles based on the format requested by the client.

Figure 26 — DCS Client — OGC Tiles API — Geopackage Landmarks (NY)

5.4. Key Management System

The Key Management System (KMS) for Testbed-17 provides an API that offers the registration and fetching of Data Encryption Keys (DEK). The KMS supports key creation and key owners to specify access conditions for each of their DEK via portal pages, accessible after login. In
addition, the KMS also offers an API for the registration of Key Encryption Keys (KEK) in order to encrypt responses that contain a DEK.

![Key Management System OpenAPI](image-url)

**Figure 27 — KMS API in OpenAPI**
5.5. Data Encryption Key Creation

A key's lifetime begins with its creation. This can take place in an encryption service like the DCS Server, offline or via the KMS admin interface. After the time of creation, no data has been ciphered yet and so the usage of the key is encryption. At the stage of encryption, the key might not be available for decryption purposes.

The following figure shows the KMS portal page for creating a Data Encryption Key.

![KMS Portal Page for Creating a Data Encryption Key](image)

**Figure 28 — KMS Input form for Creating a Data Encryption Key**

When creating a DEK via the KMS, the user must provide different types of information:

- PIN or secret that is required when adopting the access conditions of the key via the KMS Admin Portal.
- Audience is the UUID of the application that gets immediate access the key (if the Check to activate key option is selected). Additional applications can be added via the KMS Admin Portal. In the case where the DCS client shall be used for creating encrypted content based on the created key, the DCS client's UUID must be provided. If AUTHENIX is used as the Authorization Server, the UUID of the application can be found [here](#).
• **Expires** determines the initial expiration time of the key. The expiration time can be changed via the KMS Admin Portal.

• **Cipher Algorithm** is a list of symmetric ciphers as illustrated in Figure 29. The top of the list is used with JWK and the list identified with URIs is used specifically for XML Encryption.

• **Check to activate key** option allows to make the key available immediately to the application specified above and until the expiration time.

In case a key was created offline or created by the DCS Server, the key must be registered with the KMS as no protocol exists that would allow the direct exchange of the DEK between the DCS client and the DCS Server.

### 5.6. Data Encryption Key Registration

The KMS offers an API for the (automated) DEK registration. The KMS API supports different options:

*Choose...*

- A128CBC-HS256
- A192CBC-HS384
- A256CBC-HS512
- A128GCM
- A192GCM
- A256GCM

http://www.w3.org/2001/04/xmlenc#aes128-cbc
http://www.w3.org/2001/04/xmlenc#aes192-cbc
http://www.w3.org/2001/04/xmlenc#aes256-cbc
http://www.w3.org/2001/04/xmlenc#tripledes-cbc
http://www.w3.org/2009/xmlenc11#aes128-gcm
http://www.w3.org/2009/xmlenc11#aes192-gcm
http://www.w3.org/2009/xmlenc11#aes256-gcm

*Figure 29 — KMS Ciphers for Data Encryption Key*
- the DEK can be uploaded via HTTP POST and the KMS created the key’s identifier (kid in JWK terminology) via the `DEK/addKey` operation
- the client application creates a UUID based identifier for the DEK and uploads the key via HTTP PUT to a URI including the key’s identifier via the `DEK/addKeyById` operation. In case that another key with that UUID already exists, the response is HTTP Conflict.

The HTTP response to the POST and PUT operation will contain the key identifier(s) that can be used with the GET operation to fetch the key details including the key’s secret.

### 5.7. Data Encryption Key Deletion

A DEK can be deleted from the KMS via the `DEK/delKeyById` operation. Compliant to the NIST 800-57 recommendation and to ensure that key identifiers are unique, the HTTP DELETE option does delete the key’s secret and deactivates the key so that it can no longer be fetched via the KMS API (the KMS will return a HTTP GONE if the key is requested after the deletion). Even though the key could still be reactivated via the Admin Portal, it is useless as the secret (k) value is set to NULL.

### 5.8. Data Encryption Key Access Management

Once a DEK is registered with the KMS, the owner of the key can modify the access conditions after login. Key ownership is identified via the PIN that a user submitted when creating a DEK via the portal pages or the DCS client submitted with the request for encrypted content via the `key_challenge` parameter.

The user must login to the KMS for viewing and adjusting access conditions to their DEK(s). Once logged in, the KMS displays a list of all keys accessible to the user (see Figure 30).
The user can open the access management page by clicking on the link for a particular key. As illustrated in Figure 31, the use has different options to constraint access.
Before you can renew the current usage conditions for this Data Encryption Key:

Key: 66c62b27f7e0-407a-8a2a-1de3ac65a570
Issued at: 2021-09-27T07:14:47+09:00

Please adapt the usage to your needs below:

Active or Deactivate this key
Check to activate the key under the usage as specified below

PIN for this key
Type pin for key

Provide list of usage based on user’s email
Type email for user

Provide list of usage based on user’s UUID
Type UUID for user

Provide list of usage based on application UUID
Type UUID for application

Current usage based on time in UTC

Please select the start time that this key can be renewed. Please select the end time until this key can be retired.

Current usage based on geographic area

Update Key Usage

Figure 31 – KMS Access Management Page
• PIN: In order to change access conditions for the key, the user must provide the PIN. The blue ? can be clicked to check if the PIN is correct. If so, the icon will change to a green check-mark; if incorrect, the icon will change to a red X.

• activate: The activate option controls whether the key can be requested via the DEK/getKeyById operation at all. If unset, the key cannot be fetched from the KMS, regardless of the conditions specified. This is a kind of emergency override to stop release of the key.

• shared via email: The next option allows to make the key available to users based on their email address(es). Please note that the email address of a user depends on the login provider chosen when logging in via AUTHENIX. If the OGC IdP is used for login, then the email address is equivalent to the email address shown in the OGC Portal; if logged in via Google, the user’s Gmail address must be used for sharing.

• shared via user Id: In case that the key shall be shared with user(s) but the users do not want to provide their email address(es), the user can provide their UUID. The UUID is displayed once logged into AUTHENIX. The user’s identifier UUID is displayed at the bottom of the page. It is the value for the sub attribute name. This honors the privacy of the users as coined in European Union’s General Data Protection Regulation (GDPR).

• shared via application Id: Any application that needs to obtain a DEK from the KMS must first be registered with AUTHENIX and the client_id UUID from the registration result must be put into the application UUID box. Any application that is currently registered with AUTHENIX can be found following the Operators link. For example, the OGC Token App used for various demonstrations has UUID 019b7173-a9ed-7d9a-70d3-9502ad7c0575 and the DCS client that supports decryption of GeoPackages with Encryption Extension has UUID 8d90bc42-4401-5f2a-9054-cb407a876ad8.

• temporal conditions: Next, the user can specify the time window of access. The from time can be set to the future which is an important feature if encrypted data is packaged on some mobile devices and they are shipped to their final destination. While the devices are in transit, the associated decryption key cannot be accessed.

• spatial conditions: In addition to the temporal conditions, also geospatial conditions can be added. The selection of multiple polygons allows access to be constrained to particular areas. This ensures for example that mobile devices can only obtain the decryption key if within the ‘green’ area.

The registration and fetching of DEKs require that the request contains a Bearer access token issued by AUTHENIX. From the Bearer access token, the KMS determines the acting user (sub) and the application that issued the API request (aud). These two pieces of information are essential key access conditions.
6

TECHNOLOGY INTEGRATION EXPERIMENTS (TIES)
TECHNOLOGY INTEGRATION EXPERIMENTS (TIES)

The TIEs for the Testbed-17 DCS task were grouped into multiple tests for each of two scenarios. Testbed-17 primarily focused on applying DCS to binary geospatial data (maps and tiles) and geospatial data sets in GeoPackage container format (tiles and features). The TIEs are divided into sub-TIEs as follows:

- Provisioning and portrayal of DCS protected geospatial binary content.
- Provisioning and portrayal of DCS protected layers of geospatial vector and binary content in GeoPackage format.

The TIEs are executed between the DCS Server and the DCS Client, both implemented within Testbed-17.

6.1. TIE Setup

Common to all tests is that the DCS Server provides the DCS capabilities “on top” of regular OGC API requests by requiring the calling application to submit additional parameters:

- OAuth2 Bearer Token as specified in RFC 6750. The bearer token identifies the acting user.
- key_challenge as specified for code_challenge in RFC 7636
- key_challenge_method as specified for code_challenge_method in RFC 7636
- kek_kid or kek_uri as specified in Annex Clause 5.2: A private RSA key previously registered with the KMS.

6.1.1. Client prepares to send request to DCS Server

For Testbed-17, the DCS Client is implemented as a Mobile Application. This is a short summary of the interactions between the client application and the DCS Server:

- Mobile application uses the OAuth2 Authorization Code Flow to obtain a Bearer Token from the Authorization Server AUTHENIX.
- Mobile application creates private key for acting user and registers the RSA asymmetric key with the KMS.
• Mobile application asks the user for a password, pin or secret to protect the Data Encryption Key. This user input is used by the application as value for key_challenge parameter. It is recommended that the application uses key_challenge_method=S256.

• Mobile application sends OGC API request to DCS Server accompanied by the specific parameters outlined above. Parameter f controls the response format.

The client application must undertake the following steps (simplified summary) to decrypt the response from the DCS Server:

• The DCS Server response contains data and metadata encrypted with different DEKs (Data Encryption Keys). The keys are not included in the response. The client application must process the response to find the key identifier and/or the key URL to fetch the DEKs from the KMS.

• Mobile client starts interaction with the KMS retrieving cryptographic keys required to decrypt previously fetched protected content (binary geospatial data and GeoPackages).

• The resulting data set was retrieved, and the key_id values were extracted from the metadata section of the response.

• Key retrieval is done via the KMS component implemented in Testbed-16. The interaction with its API occurs by passing key identification strings extracted from the metadata section of protected content as well as a Bearer Token identifying the acting user and client application.

• Mobile client decrypts the payload and renders the content.

6.1.2. DCS Media Types and OGC APIs

NOTE: A future standardization should fix the media types and have them registered with the appropriate authority — i.e. IANA.

Testbed-17, as an extension to Testbed-16, allows fetching different kinds of DCS content from different OGC API implementations:

Table 2 — OGC API DCS Media Types

<table>
<thead>
<tr>
<th>OGC-API</th>
<th>DCS MEDIA TYPE</th>
<th>DESCRIPTION</th>
<th>URL EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Features</td>
<td>application/dcs+geo</td>
<td>DCS container structure encrypted features, metadata as JSON</td>
<td>URL_1a</td>
</tr>
<tr>
<td>Features</td>
<td>application/dcs+geo;profile=metaSign</td>
<td>DCS container structure encrypted</td>
<td>URL_1b</td>
</tr>
<tr>
<td>OGC-API</td>
<td>DCS MEDIA TYPE</td>
<td>DESCRIPTION</td>
<td>URL EXAMPLE</td>
</tr>
<tr>
<td>---------</td>
<td>----------------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Features</td>
<td>application/dcs+geo;profile=metaEncrypt</td>
<td>DCS container structure encrypted features, metadata as JWE</td>
<td>URL_1c</td>
</tr>
<tr>
<td>Features</td>
<td>application/gpkg+dcs</td>
<td>GeoPackage with encrypted features</td>
<td>URL_2</td>
</tr>
<tr>
<td>Tiles</td>
<td>application/gpkg+dcs</td>
<td>GeoPackage with encrypted tiles</td>
<td>URL_3a and URL_3b</td>
</tr>
<tr>
<td>Maps</td>
<td>application/dcs+{png,jpeg,...}</td>
<td>MultiPart response with encrypted map</td>
<td>URL_4</td>
</tr>
</tbody>
</table>

**URL_1a**

**URL_1b**
https://ogc.secure-dimensions.com/geoserver/ogc/features/collections/tiger:poi/items?access_token=<your_access_token>&key_challenge=secret&key_challenge_method=plain&f=application%2Fdcs%2Bgeo;profile=metaSign&limit=1

**URL_1c**
https://ogc.secure-dimensions.com/geoserver/ogc/features/collections/tiger:poi/items?access_token=<your_access_token>&key_challenge=secret&key_challenge_method=plain&f=application%2Fdcs%2Bgeo;profile=MetaEncrypt&kek_kid=859f22b4-1ce1-42c0-8668-aac789c79242&limit=1

**URL_2**

**URL_3a**
Loading all tiles of a TileMatrix

---

**Large size and processing time**

Please use this option with care! Encrypting all tiles for a TileMatrix might take a very long processing time and produce large responses!!! For example, changing the URL below to process TileMatrix EPSG:4326:21 produces a 12GB response with processing time of some 6 hours!!!
Large size and processing time

Please use this option with care! Encrypting all tiles for a TileMatrixSet might take a very long processing time and produce large responses!!! E.g. for the example URL below, the f=application/zip produces a 7.5MB file that is returned after some seconds. Using the f=application/gpkg+dcs produces a 92MB response in some 30 seconds.

Use valid Access Token

Please use the Token App to obtain a valid access token and replace the <access_token> in the URL accordingly.

6.2. DCS Server Tests

This section introduces tests for validating manually that the DCS Server responses are as expected.

6.2.1. OGC API Features

The DCS Server provides two different response formats, recognized by the f parameter of the request: application/dcs+geo and application/gpkg+dcs.

6.2.1.1. Media Type application/dcs+geo

The application/dcs+geo media type returns a JSON encoded DCS container format that was developed during Testbed 16.
The expected response is a JSON encoded DCS container comprised of a metadata and a data element. The data element contains the encrypted feature in JWE encoding with compact serialization. The metadata element is JSON encoded.

```
{
  "type": "DCS",
  "objects": [
    {
      "metadata": {
        "originator_confidentiality_label": {
          "confidentiality_information": {
            "policy_identifier": "TB17",
            "classification": "Top Secret"
          }
        },
        "data_producer": {
          "origin": "Not NGA",
          "date": "2021-08-31T10:22:37.537Z"
        },
        "data_description": {
          "type": "Feature",
          "properties": {
            "name": "poi",
            "namespace": "http://www.census.gov",
            "content_type": "application/geo+json"
          },
          "geometry": {
            "type": "Point",
            "coordinates": [-74.0104611, 40.70758763]
          }
        }
      }
    },
    {
      "data": "eyJpc3MiOiJodHRwczpcL1wvb2djLnNLY3VyZS1kaW1lbnpb25zLmNvbSIsIm0eSI6ImFwcGxpY2F0aW9uX2FpZC5hZG1pbnQifQ."
    }
  ],
  "totalObjects": 1,
  "numberMatched": 1,
  "numberReturned": 1,
  "timeStamp": "2021-08-31T10:22:37.541Z",
  "links": []
}
```
The JWE in the data element must contain the DEK's kid.

```
{
  "iss": "https://ogc.secure-dimensions.com",
  "cty": "application/dcs+geo",
  "enc": "A256GCM",
  "alg": "dir",
  "kurl": "https://ogc.secure-dimensions.com/kms/keys/4c98fa0a-a212-4d6a-8ced-d8cb5d6b2e7e",
  "kid": "4c98fa0a-a212-4d6a-8ced-d8cb5d6b2e7e"
}
```

Base 64 decoded JWE header

### 6.2.1.2. Media Type application/gpkg+dcs;profile=metaSign

The expected response is a JSON encoded DCS container comprised of a metadata and a data element. The data element contains the encrypted feature in JWE encoding with compact serialization. The data_description element of the metadata element is JWS encoded with compact serialization.

```
{
  "type": "DCS",
  "objects": [
    {
      "metadata": {
        "originator_confidentiality_label": {
          "classification": "Top Secret"
        }
      },
      "data_producer": {
        "origin": "Not NGA",
        "date": "2021-08-31T10:33:42.957Z"
      },
      "data_description": "eyJqa3UiOiJodHRwczpcl1vb2djlLnNLy3VvZS1kaW1lbmNvb25zLmNvbW9vZGNCX8ud2VsbC1rbm93blwvan...gEBnG-K4SdrqvDIVDAChr_uibPNV3SnLzQzhY_R0iCjG1P2X5uOj9FXL3JFgDuteHoyLoIIfhH5yYosmJygAoqJqBKHZ3TR97sire4cq84Y51MP9ed7-9woyRzQISXb1UF220cmqtp-eX3Nf13tam8RrA5LQ"
    }
  ]
}
```
The JWE in the data element must contain the DEK's kid.

```
{ "iss": "https://ogc.secure-dimensions.com",
  "cty": "application/dcs+geo",
  "enc": "A256GCM",
  "alg": "dir",
  "kurl": "https://ogc.secure-dimensions.com/kms/keys/2844436e-c36a-44fb-84c3-43f02989ee7e",
  "kid": "2844436e-c36a-44fb-84c3-43f02989ee7e" }
```

Base 64 decoded JWE header

The JWS in the data_description element must specify the public key reference (jku) of the issuer's public key and the kid.

```
{ "jku": "https://ogc.secure-dimensions.com/.well-known/jwks.json", } 
```
6.2.1.3. Media Type application/gpkg+dcs;profile=metaEncrypt

The expected response is a JSON encoded DCS container comprised of a metadata and a data element. The data element contains the encrypted feature in JWE encoding with compact serialization. The data_description element of the metadata element is JWE encoded with compact serialization.

```json
{
  "type": "DCS",
  "objects": [
    {
      "metadata": {
        "originator_confidentiality_label": {
          "confidentiality_information": {
            "policy_identifier": "TB17",
            "classification": "Top Secret"
          }
        },
        "data_producer": {
          "origin": "Not NGA",
          "date": "2021-08-31T10:43:16.005Z"
        },
        "data_description": "eyJraWQiOiI4NTlmMjjiNC0xY2U2LyAtODY2OC1hYWMXM0JlNyNzNkYiI6InN0eSI6IjFzdGVtZGVyc2FrIiwiaWQiOiJodHRwczpcL1wvb2RlLmNvbSIsImN0eSI6IiJ9",
        "data": "eyJpc3MiOiJodHRwczpcL1wvb2RlLmNvbSIsImN0eSI6IiJ9.X.
    }
  ]
}
```
57VH7xL0kk3QjoGrj0g8m6vrRcvry5EnUAXkUDvjtNfcRtBnoFM6BGdg5jPpFm3iMy3k1n8yXWKQ_fKsIdsjEkqEkE-YM-9ppHg8qYtSHc_wnlkyBaZ138cxA1FaUvj3D03uTExmo7tyrBGMX_1R6NEQDyVRRBznt0Mhp0xyBprTmxg7823Nz1hgRQd6rrqPpuLqWiaq7NMJc5nEyaMSkgU4cPyra7i3rPjdbNZt5k57D8tnJmsdEICVE0AXPuKUpCPh3h1YnuvC0STfHcN9jxmeI4hwDyxFpnuFuoIhUPJc9jUXsNyX4q1x6b9dyt7LH1ncMgJo1S5t3wz6s6dhM9-RBT2xVUX2QFhrNkWlhSj_t1zg8Cy29c-dHdd5uTg9KQz8AtpcG0HURLr27ZZ03GLUL1BftrL5u-LxuiftnohDmg5ga64Wapgf2poevGDyzpPTYZS3GuEwNkTqdamCI1Wgu2lrKifgbaLTYWJpxnx-nywRNc9W7UWhRqG5d_dieqznEbgFfGJcQzvOPxm6jN7BvfWHzQ9F2t8g7GiGcrLAI55lh9Q8NOWvxFLicCrc4m6IjQqjNQWefLnjN7TLajSA4Xy9zh250KPNIsEdGzotW_3a76Cxd_C6hjs2uThersj5G3Kpt4Y-fgjv7g4osD58yiXk0264lr_Qy31z7bMUugRqO-MWtImbZ_i8D_J0YKlbn4Uoiyhg5QHbh9t49QRYYMDRLVdyccPQ0WeNU9spSUTG0xW0.g-nV2gyDYTnzTH0qLuBEQQ"
]
],
"totalObjects": 6,
"numberMatched": 6,
"numberReturned": 1,
"timeStamp": "2021-08-31T10:43:16.009Z",
"links": [
{
"title": "next page",
"type": "application/dcs+geo",
"rel": "next",
"href": "https://ogc.secure-dimensions.com/geoserver/ogc/features/collections/tiger:poi/items?access_token=a7b05c5df39c47bb94148a1cdcf081876da5f50key_challenge=secret&key_challenge_method=plain&f=application%2Fdcs%2Bgeo%3Bprofile%3DmetaEncrypt&kek_id=859f22b4-1ce1-42c0-8668-aac789c79242&limit=1&bustCache=0.5590496976910175&startIndex=1"
}
]
}

**Expected Response for URL_1c**

The JWE in the data element must contain the DEK's kid.

```
{"iss": "https://ogc.secure-dimensions.com",
"cty": "application/dcs+geo",
"enc": "A256GCM",
"alg": "dir",
"kurl": "https://ogc.secure-dimensions.com/kms/keys/93df27c6-5174-4b1d-b652-704a42d4df31",
"kid": "93df27c6-5174-4b1d-b652-704a42d4df31"
}
```

**Base 64 decoded JWE header**

The JWS in the data_description element must contain the KEK's kid. The value of the kid must be equivalent to the value of the request parameter kek_id. The private key, associated to the public key, must be used to decrypt the content.

```
{"kid": "859f22b4-1ce1-42c0-8668-aac789c79242",
"cty": "JWE",
"enc": "A256GCM",
"alg": "RSA-OAEP-256"
}
```

**Base 64 decoded JWS header**
6.2.1.4. Media Type application/gpkg+dcs

The application/gpkg+dcs media type returns a GeoPackage extension that stores encrypted features as described in Annex A — GeoPackage DCS Features Extension.

6.2.2. OGC API Tiles

The DCS Server provides one response format, recognized by the f parameter of the request: application/gpkg+dcs. The actual image format of the tile is controlled via the f-tile parameter. Valid values for the f-tile parameter depend on the actual data deployment; most often image/png and image/jpeg are supported.

NOTE: For simplification, the TIEs and tests use the image/png format only.

6.2.2.1. Media Type application/gpkg+dcs

The application/gpkg+dcs media type in combination with image/png returns a GeoPackage container that contains all requested tiles honoring the GeoPackage extension defined in Annex Annex A — GeoPackage DCS Tiles Extension.

6.2.3. OGC API Maps

The DCS Server provides one response format, recognized by the f parameter of the request: application/dcs+png or application/dcs+jpeg.

NOTE: For simplification, the TIEs and tests use the PNG format only.

6.2.3.1. Media Type application/dcs+png

The application/dcs+png media type must return a HTTP Multipart response, where the first part contains the JSON encoded metadata and the second part the encrypted image as octet-stream. The response content-type must be multipart/encrypted denoting as a profile the protocol format that provides the metadata for the encrypted binary data.

Message-ID: 35d58964-dd70-4c99-b163-d4de161a48a1
Content-Type: multipart/encrypted; protocol="application/json"; boundary=ce5b9207-6e4b-4ba0-8632-9964aae0a927
Date: 2021-08-31T12:41:33+0100

--ce5b9207-6e4b-4ba0-8632-9964aae0a927
Content-Disposition: inline
Content-Type: application/json
Content-Length: 1420

{"metadata":{"originator_confidentiality_label":{"confidentiality_information":
"policy_identifier":"TB17","classification":"Confidential"}},"data_
The metadata returned as the first part must include a dek_info element that contains a JWT defining the issuer of the response as well as DEK information.

```
{
    "jku": "https://ogc.secure-dimensions.com/dcs/.well-known/jwks.json",
    "kid": "Dr. No",
    "alg": "RS256"
}
```

**Base 64 decoded JWT header**

```
{
    "sub": "ff1045c2-a6de-31ad-8eb2-2be104fe27ea",
    "aud": "019b7173-a9ed-7d9a-70d3-9502ad7c0575",
    "kurl": "https://ogc.secure-dimensions.com/kms/keys/a2e43d1f-3761-452b-b55a-9f5f68304afe",
    "kid": "a2e43d1f-3761-452b-b55a-9f5f68304afe",
    "iss": "https://ogc.secure-dimensions.com",
    "exp": 1630411,
    "alg": "A128GCM",
    "iat": 1630410091822
}
```

**Base 64 decoded JWT payload**

The second part must use Content-Disposition: inline and Content-Type: application/octet-stream. Using the kid=a2e43d1f-3761-452b-b55a-9f5f68304afe must allow to decrypt part two of the response.
6.3. Provisioning and portrayal of DCS protected geospatial binary content

The DCS enablement requires an extension to a standard OGC API request with additional query parameters. Depending on the API and the response format, different additional parameters are mandatory.

The following table illustrates which parameters are required:

<table>
<thead>
<tr>
<th>OGC-API</th>
<th>F</th>
<th>ACCESS_TOKEN</th>
<th>KEY_CHALLENGE</th>
<th>KEY_CHALLENGE_METHOD</th>
<th>KEK_ID</th>
<th>XOR</th>
<th>KEK_URI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Features</td>
<td>application/dcs+geo</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td></td>
<td></td>
<td>o</td>
</tr>
<tr>
<td>Features</td>
<td>application/dcs+geo;profile=metaSign</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td></td>
<td></td>
<td>o</td>
</tr>
<tr>
<td>Features</td>
<td>application/dcs+geo;profile=metaEncrypt</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td></td>
<td>m</td>
</tr>
<tr>
<td>Features</td>
<td>application/gpkg+dcs</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td></td>
<td>m</td>
</tr>
<tr>
<td>Maps</td>
<td>application/dcs+png</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td></td>
<td>o</td>
</tr>
<tr>
<td>Maps</td>
<td>application/dcs+jpeg</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td></td>
<td>o</td>
</tr>
<tr>
<td>Tiles</td>
<td>application/gpkg+dcs</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td></td>
<td>m</td>
</tr>
</tbody>
</table>

6.4. TIE Results

TIEs are conducted between the DCS Client Application (Mobile App) and the DCS Server. A successful TIE requires that the DCS Client and the DCS Server interact with the Authorization Server (AUTHENIX) and the Key Management System (KMS).

6.4.1. DCS Client TIE

As illustrated in an earlier section, the DCS Client Application must obtain a valid OAuth2 Bearer Token from the Authorization Server. Depending on the requested response format
(profile=metaEncrypt), the Client Application must register the user’s public key (once) with the KMS. Because a public key (for this Testbed) does not expire, the Client Application can re-use a previously registered public key, but still the one-time registration is required.

Therefore, the TIE for the DCS Client is split into these individual TIEs:

- Interaction with the Authorization Server
- Interaction with the Key Management System
  - for registration of user's public key
  - for fetching DEK(s) to decrypt the response
- Interaction with the DCS Server

A final TIE determines whether the Client Application is capable of decrypting the response from the DCS Server and is able to render and display the geospatial content.

Table 4 — DCS Client TIEs

<table>
<thead>
<tr>
<th>STEP</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Interaction with the Authorization Server</td>
<td>✓</td>
</tr>
<tr>
<td>Interaction with the Key Management System</td>
<td></td>
</tr>
<tr>
<td>2a. for registration of user's public key</td>
<td>✓</td>
</tr>
<tr>
<td>2b. for fetching DEK(s) to decrypt the response</td>
<td>✓</td>
</tr>
<tr>
<td>3. Interaction with the DCS Server</td>
<td>✓</td>
</tr>
</tbody>
</table>

6.4.2. DCS Server TIE

The DCS Server must accept an OGC API DCS request as defined above. A valid request must produce the expected result as outlined above. In order to produce the response, the DCS Server must interact with the Authorization Server and the Key Management System.

Therefore, the TIE for the DCS Server can be separated into these individual TIEs:

- Interaction with the Authorization Server (for the purpose of validating Bearer Tokens — aka access_token)
- Interacting with the KMS to register generated DEKs
Interacting with the KMS to fetch public key (determined by the kek_kid or kek_uri parameter)

Table 5 — DCS Server TIEs

<table>
<thead>
<tr>
<th>STEP</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Interaction with the Authorization Server</td>
<td>✓</td>
</tr>
<tr>
<td>Interaction with the Key Management System</td>
<td></td>
</tr>
<tr>
<td>2a. for fetching the user's public key</td>
<td>✓</td>
</tr>
<tr>
<td>2b. for registration of the DEK(s) used for encryption</td>
<td>✓</td>
</tr>
</tbody>
</table>

6.5. TIE Summary

A successful TIE can be determined by the ability of the DCS Client to query, decrypt (and display) the encrypted DCS response from the DCS Server. When that is the case, all outlined interactions must have worked as a whole.

Table 6 — TIE Summary for DCS Client and Server

<table>
<thead>
<tr>
<th>OGC-API</th>
<th>F</th>
<th>TIE RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Features</td>
<td>application/dcs+geo</td>
<td>✓</td>
</tr>
<tr>
<td>Features</td>
<td>application/dcs+geo;profile=metaSign</td>
<td>✓</td>
</tr>
<tr>
<td>Features</td>
<td>application/dcs+geo;profile=metaEncrypt</td>
<td>✓</td>
</tr>
<tr>
<td>Features</td>
<td>application/gpkg+dcs</td>
<td>✓</td>
</tr>
<tr>
<td>Maps</td>
<td>application/dcs+png</td>
<td>✓</td>
</tr>
<tr>
<td>Maps</td>
<td>application/dcs+jpeg</td>
<td>✓</td>
</tr>
<tr>
<td>Tiles</td>
<td>application/gpkg+dcs</td>
<td>✓</td>
</tr>
</tbody>
</table>

The successful TIEs were conducted between DCS Client Application and DCS Server.
7

TOWARDS DATA CENTRIC SECURITY AND FEDERATED SECURITY
TOWARDS DATA CENTRIC SECURITY AND FEDERATED SECURITY

NOTE: The goal of this section is to analyze the gaps between the DCS architecture and implementation solution developed in Testbed-17 towards its use in Federated Security.

During OGC Testbed 15-17 Data Centric Security activities, an architecture was developed that supports adding security when requesting geospatial data using one or more OGC APIs. The components of the architecture, as illustrated in Figure 1, require having access to a common (shared) security context. For the implemented solution, the exchange of the security context is coupled with the Bearer Access Token, created with a single Authorization Server. For a single security domain, as defined by the Authorization Server, this is common practice. Different major solutions in mainstream IT function exactly like this: Resources are protected by Security Proxies that check OAuth2 tokens for validity, user and audience conditions. With the extension of OAuth2 based on OpenID Connect, hybrid flows are used that also allow exchanging personal information as part of the security context. However, these solutions do not allow, for example, a user that has authenticated with Google to access Facebook resources. The user must authenticate with Facebook which will then give the application a Facebook token.

With Federated Security, users from different security domains are able to act on resources provided by operators from different security domains with applications from different security domains. As outlined in the Federated Security ER, different approaches exist to establish trust between applications, services and actors from different security domains.

This section analyses gaps between the existing DCS architecture and functioning in a Federated Security setup.

7.1. Overview

So far, the DCS solutions developed in Testbed 15-17 were demonstrated inside of an individual “Administrative Domain” (AD) that essentially comprised of:

- An Authorization Server that connects to an Identity Provider (IdP).
- A (Cloud) Service Provider (SP).
- A (mobile) client application.
- A user authenticated within the AD.

The relevant context of Federated Security is described in different (complex) publications:

The target architecture for supporting DCS with Federated Security is based on the Zero Trust Domain definition, where, in contrast to perimeter-based security, each interaction requires authentication and is subject to access control; literally trust nobody — verify all (users). With such a target architecture, where all interactions between a user-controlled application and secured services require authentication, there needs to be a solution for how to trust users that are authenticated in another domain. This implies the first topic to be analyzed: How can the existing DCS architecture be extended to support federated authentication?

As the Zero Trust can be coined to be data centric — each data flow is subject to being controlled — the question arises of how to establish such a control mechanism for encrypted data. With encrypted data, the typical access control approach no longer works, as the encrypted data must be treated as a BLOB or a black box. With data in the clear, the data itself can be used to derive fine grained access control, as it is possible with OASIS’s XACML or OGC’s GeoXACML. This challenge can be identified as the second important topic to be analyzed: How can access to encrypted (geospatial) data be controlled towards users authenticated in their own domains, as well as authenticated in another (federated) domain?

The overall question to analyze can be summarized as follows: “Is it actually possible to extend a single-domain DCS architecture to function equivalent in a Federated Security environment? Or, must limitations / constraints be defined that reduce the flexibility of the architecture with transiting towards federated support?

### 7.2. Implications to Authentication

The existing DCS architecture causes all authentication to be performed in one single Authorization Server. Even though the Authorization Server in place (AUTHENIX) is based on federated identity management — it allows users to login with accounts from multiple domains — the Bearer Access Token linked to the user is validated with AUTHENIX. Also, the personal data that is linked to the access token can only be fetched from AUTHENIX. Extending the architecture from a single domain to multiple domains implies that either all domains trust the authentication to be done by AUTHENIX or that each domain operates their own Authentication Service.

At this point, the option that one Authorization Server operates as the only trusted authentication service can be ignored. So, assuming that each (Zero Trust) domain will operate their own Authorization Server, what implications to the remaining architecture exist? Each service in a Zero Trust Domain environment that provides access to data must be able to validate the (claimed) identity of the acting user.

One typical solution to extend authentication from one single to a federated infrastructure can be based on digitally signed assertions. These assertions can be either authentication, authorization or other security context statements. The OASIS Security Assertion Markup Language (SAML) is, for example, the backbone of federated identity management for eduGAIN, the federation of many academic institutions around the globe. In a nutshell, the setup of federated identity management requires to roll-out a PKI where typically Certificates vouch...
for the identity of an assertion. The assertion is trusted by the receiving party, if the digital
signature can be verified to be from one of the trusted domains. Each domain operating an
Identity Provider must exchange their X.509 certificate in advance. Applying such a concept
to the existing DCS solution, the use of Bearer access tokens could be changed to Digitally
Signed access tokens. The use of JWT, as described in JSON Web Token (JWT) is a possibility.
Establishing a trust federation of Authorization Servers and what it all needs is described in
OpenID Connect Federation 1.0 — draft 17. Comparing the approach with SAML, it seems that
the principles are somehow identical, but the protocol is more modern: JSON instead of XML.

Another interesting effort is the one regarding W3C Secure Payment Confirmation where
the objective is “...to scale authentication across merchants, to be used within a wide range of
authentication protocols, and to produce cryptographic evidence that the user has confirmed
transaction details.”

Any extension from one single authentication source to a federated variation has direct
implications to access control.

7.3. Implications to Access Control

When users reside in a single security domain, the authentication process can ensure that all
user attributes become available that are required to undertake access control. However, when
extending authentication into a federation, the access control decision, derived locally, might
lack required user attributes. The cause of that could be that either the required attribute is
not available at the other authentication service or that the attribute is simply not released
to another domain. An example for the first case can be found when using the Testbed-17
Authorization Server and the login via the OGC Portal IdP. An authenticated user from OGC will
have the OGC related claim ogc-is-member-of which is part of access control in Testbed-17.
This claim lists all the user’s active OGC projects (DWG, SWG and project membership). When
the same user uses Facebook, Google, or a University login, this particular claim is not available.
Examples for withheld attributes can be found in the intelligence but also eduGAIN domain: user
attributes that are considered sensitive (e.g. military ranking, personal information stored at a
University) may not be released to other domains.

The other implication / complication to access control is the harmonization of access rights
and their interoperable exchange. Based on the fact that in each Zero Trust Domain access
control is done in isolation from other domains, how can it be ensured that one user gets access
granted to a composite of services as required. As an example, a disaster management first
responder requires access to information that is provided by services from different (Zero Trust)
domains. There must be some (pseudonymize) unique identifier of the user that allows binding
access rights in the local domain. This access control management objective has implication to
authentication: All users — regardless of origin domain — must be identified via a globally unique
identifier (unique and persistent across all acting authorization servers).

Assuming that each user can be uniquely identified, it is still possible that the user gets an HTTP
status code 403 meaning access to the requested resource was forbidden. As the user is stuck in
security, this message may not be particularly helpful. The resulting challenge is how to help the
user or the application to “understand” what the issue is. This opens the challenge to know how
much information can be exposed securely; remember: a Zero Trust Domain means “don't trust anybody”. This implies that there won't be any information available to help the user, as they are not trusted (and could be an adversary). But still, there must be some mechanism or protocol that helps to “bootstrap” a solution, assuming there was a legitimate request issued in the first place. Further analysis is required towards the question: How to determine the trustworthiness of a user in particular cross domain.

Another daring challenge is the exchange of access conditions among administrators of different domains for the purpose of harmonizing the access rights of users. The assumption is that the actual access control realization in each domain is done specifically, honoring different facets specific to the domain. But how can access conditions be exchanged with other domain admins to ensure that access requirements can be managed? Further analysis should determine how far the use of Access Control Markup Languages like XACML or GeoXACML help to (automatically) harmonize access conditions across domains.

Extending access control to encrypted data has implications for Key Management.

### 7.4. Implications for Key Management

During OGC Testbed 16, a Key Management System (KMS) was developed to protect the data decryption keys used to encrypt geospatial data. The functionality of the KMS was inspired by the NIST Special Publication 800-57 Part 1, Revision 5, Recommendation for Key Management: Part 1 – General publication. In particular the key’s lifecycle and the separation of data encryption and key encryption keys was implemented. A Data Encryption Key (DEK) is the actual cipher key that scrambles the data. The possession of DEK enables decrypting the actual data. A Key Encryption Key (KEK) is a cipher key that is used to encrypt a DEK for storage or transit. Typically, a DEK is a symmetric key (shared secret) and a KEK is an asymmetric key (private — public key pair). In that regard, the use of the keys is different and so are implemented options for constraining access to the keys. Regardless if DEK or KEK, the key registration requires the user to authenticate. The registration of the KEK is limited to public keys. The assumption is that the matching private key is securely stored with the owning user. The fetching of the public KEK is open to all users as encryption based on the public key can only be decrypted by the associated private key. Further, per definition, their key is only in permission of the user. However, to prevent misuse in case the private key is leaked, the KMS supports the owner of the KEK deleting the key.

The KMS allows the owning user to apply fine grained access control to a DEK, as illustrated in Clause 5.8. However, the access control is not tied to the actual content that originally existed before encryption. For example, constraining access to encrypted information based on feature_type or classification is not possible via the KMS. Further analysis is required to determine how far the encryption process itself can reflect the original data’s characteristics. For example, the Testbed-17 DCS Server uses different cipher algorithms for data that is (artificially marked as CLASSIFIED, SECRET, TOP SECRET). However, the KMS does not constrain access based on the key algorithm. So, what seems to be missing is metadata on the usage of the key and which characteristics of the encrypted data exist that should be considered for access control to the DEK.
What are the implications imposed by federated authentication? The Testbed KMS relies on authentication from the single Authorization Server. Sharing of encrypted data, based on sharing access to the associated DEK can be based on the user's email or unique identifier. But what is the user's email or identifier in a federated setup? How does the KMS know which Authorization Server to contact if users from multiple domains are considered?

Assuming that each Zero Trust Domain wants to operate their own DC Server, what implications to the protocol between the DC Server and the KMS exist? What about the protocol between the DCS Client application and the KMS?

### 7.5. Implications to the DCS Server

The Testbed-17 DCS Server offers requesting encrypted (geospatial) data hosted on a GeoServer implementation of the OGC Maps, Features and Tiles APIs. Regarding the encryption key, the DCS generates a DEK on behalf of the user. However, different options are possible:

a) The user requests encrypted content but leaves it to the DCS Server to generate the encryption key (DEK) on behalf of the user;

b) The user generates the encryption key (DEK), registers it with the KMS and submits the key ID with the request.

c) The user generates the encryption key and submits it with the request to the DCS.

For the first option, where the DCS Server generates the DEK on behalf of the user, the question is which KMS to use for key registration. To enable the DCS Server to register a key on the user’s behalf requires that the DCS server has sufficient access rights on the KMS. In order to refrain from complex access condition management across domains, perhaps the DCS Server should always register the DEK with the own KMS — the KMS operated in the same security domain.

The second option implies that the DCS Server can resolve the actual encryption key from the KMS used by the user. When not Constraining which KMS that user could have registered the key, the DCS Server needs sufficient access to fetch the key. But, would a KMS release a symmetric key to a DCS Server? Assuming that a DEK is a symmetric key, it could also be used to decrypt data. So, a copy of the key stored at the KMS or exposed via an attack might jeopardize all data previously encrypted with that key. Perhaps a DEK never crosses security domains? Perhaps a DEK only can only be fetched by trusted applications? If so, how could applications verified to be trusted?

Regarding the third option, the DEK must be protected while in transit (the request is sent via the network). Even though leveraging HTTPS does protect information sent through the TLS channel, it leaves the URL in the clear. Therefore, submitting the DEK with a HTTP GET is “unwise”, even when the key is protected by a KEK. This brings an implication to OGC API standardization: OGC API Standards should support HTTP POST as an alternative to HTTP GET. Even though the use of HTTP POST over TLS would secure the DEK while in transit, but
leveraging the transport level security mechanism is still against the philosophy of DCS: Apply security to the data — to the DEK in this case. Investigation of options applicable to protect the DEK when being submitted with the OGC API request is recommended. Is it possible / sufficient if the DEK is encrypted based on the public key of the DCS Server?

Would it be “wise” that the DCS Server accepts the (encrypted) DEK with the request? If so, would the DCS Server need to validate that the DEK actually belongs to the acting user? If not, a man in the middle attack might have replaced the encryption key with the own. It should be analyzed how a DEK’s origin (issuer and owner) can be verified in a federated environment.

7.6. Implications on the DCS Client

The DCS Client for Testbed-17 implements the OAuth2 / OpenID Connect hybrid flow to obtain a Bearer access token from the single Authorization Server for the acting user. This access token is sent with each request to the DCS Server and KMS.

The implications of extending the single domain solution to a federated “mash” of Authorization Servers would impact the client application. The application would need to know which Authorization Server to contact for login. This complexity is currently proxied by AUTHENIX as it offers the login provider discovery (IdP Discovery). Would it make sense to implement such a complex and trust intense protocol as the IdP discovery into a client application? It is possible / recommended in the first place to think of Web-based, desktop, mobile and server-side applications.

When leveraging multiple Authorization Servers, how would the client application know which access token needs to send to which service endpoint? The proper matching would require that the client application knows which service accepts tokens from what Authorization Server. Is it wise to disclose all that information to the client application? Is this feasible?

What other approaches exist to lift the burden of access token and Authorization Server / Resource Server linking management off the client application?

For decrypting data, the client application must get access to the KMS. How can a key owner associate access conditions to the client application; it might have different identities with different Authorization Servers. How to not over-complicate access condition management? The more difficult the access condition management to keys get, the more difficult the validation of the effective conditions becomes.

7.7. Implications to Security

The transition from a single source solution to a solution that works in a federated environment potentially introduces protocol vulnerabilities. How can vulnerabilities in protocols be identified to prevent or mitigate successfully attacks?
Potential security hazards must be considered when defining an interoperable protocol for a federated security DCS solution.
8

FUTURE WORK
FUTURE WORK

The following topics — more or less closely related to DCS — represent recommendations for future work.

8.1. Streaming-Ready Container Format

The GeoPackage container is a capable data storage format, but should not be created at the general user’s request. Further, when making a GeoPackage container available as an output format for a service on the Internet, establishing a resource quota is recommended.

Alternative encodings like ZIP are considered streaming-ready and do not produce a storage burden on the server. Future investigation into how far the use of a ZIP container format can be used as an alternative to GeoPackage should be considered. Perhaps the SQLite 3 ZIP extension can be used as a start. When doing this investigation, it should also be evaluated whether other alternative storage structures allow to create, store and distribute large amounts of multi-part, encrypted geospatial data in a more efficient way.

8.2. OGC APIs and Asynchronous Responses

The current protocol for most (but not all) OGC API Standards requires that a HTTP GET request returns the resource as part of the response body. This can be characterized as synchronous request and response — the client and server are maintaining a TCP channel to exchange the request and response. In situations, where the production of the response takes a very long time or the size of the container is extraordinarily large (e.g. in Testbed-17 production of an encrypted GeoPackage for all Tiles from zoom level zero to twenty one took approximately 6 hours and required 21GB of storage). By the time the response was ready to be streamed to the client, the TCP socket was already closed. For Testbed-17, the DCS Server pushed the produced GeoPackage to a Content Delivery Network (CDN), where the client could fetch the response for the request at any later time.

An important response alternative could be that an API implementation reports to the client response will be ready in 6 hours - please go 'here (URL)' to fetch it. OGC API - Processes supports such asynchronous capability. Future work should investigate how other OGC API Standards could inform the client about an alternative location of the response. If an API implementation supports the persistent storage of previously requested resources (on a CDN), there could be a ‘smart cache’ at the API that redirects requests for previously created resources to their ‘persistent’ URL right away. Such a smart cache could reduce network and processing burden and improve response times.
8.3. Authenticity and Integrity of GeoPackage

How can a GeoPackage container be made tamper-resistant or how far can Integrity be applied to a GeoPackage container (perhaps as an extension) that enables the consumer to verify that the actual copy has not been tampered with since its production. In addition to (or as an extension of) Integrity, it should be evaluated how authenticity could be applied to a GeoPackage. It seems strange that a DCS extension to GeoPackage supports storing encrypted (rows of) data but that the consumer cannot verify the origin and integrity of the GeoPackage container.

8.4. Standardization of a GeoPackage Encryption Extension to OGC APIs

The results from Testbeds 15, 16 and 17 indicate that there is a common set of requirements that exists and defines a "DCS" Building Block for OGC APIs. However, in order to achieve an interoperable solution, the overall results from these Testbeds should be collected and brought forward as an Engineering Report, written as a Draft Implementation Standard. The OGC #17-007 OGC Web Services Security standard emerged in such a way.

8.5. Direct Encryption to prevent unauthorized disclosure in Web-Applications

When the client provides the Data Encryption Key (DEK) directly to the DCS Server, it is possible to ‘simply’ encrypt the response with the provided key. This simplistic scenario is equivalent to DRM direct streaming and would apply to protect data from being captured by Web-Applications, like JavaScript based clients. In the content of (one-page) Web-Applications it should be investigated in how far the encrypted data can be protected for being captured in its original format to prevent unauthorized disclosure.

8.6. Encrypted GeoTIFF and GMLJP2

Testbed-17 participants evaluated the options for packaging encrypted geospatial data into a GeoPackage container by defining suitable extensions (for Features and Tiles). The applicability of similar approaches for GeoTIFF and GMLJP2 should also be investigated along with the
implications regarding the data and processing burden. If a solution exists, a standardization approach should be identified.

8.7. Standardization of a Key Management System API

For Testbed-16 and Testbed-17, a Key Management System amended the DCS components. The main responsibility of the KMS was to create a symmetric cipher key, its registration if created offline, and the administration of access conditions. The implementation from Secure Dimensions, based on NIST 800-57, was proven to do a "pretty good" job. However, the API is not standardized. In order to ensure the productive use of Data Centric Security, the standardization of the KMS API is paramount.

8.8. Sharing of a security context across administrative domains

For Testbed-17, a security context is exchanged with Bearer Access Tokens that are released and validated at one central Authorization Server. The Authorization server acts as the single trusted 3rd party to the DCS Server and DCS Client.

8.8.1. Federation of Authorization Servers

The first opportunity towards a federation of Zero Trust Domains could be based on establishing trust between Authorization Servers of each administrative domain. This architecture follows a recommendation from Figure 12 of the OGC Testbed-16: Federated Security Engineering Report.

8.8.2. Distributed Ledgers

Future work should evaluate the option to utilize a distributed ledger or blockchain technology to establish exchange of a security context without one single trusted party. With such an approach, perhaps trust for service catalogs, roles and attributes, policies in federation environments could be established.

8.9. Harmonization of Access Policies

Any Zero Trust Domain comprises of Authentication and Access Control, as illustrated in Figure 16 of the OGC Testbed-16: Federated Security Engineering Report. Even though the
enforcement of access conditions must not rely on any standard, the exchange of access policies to facilitate policy harmonization across domains in a federated architecture should. Also, self-contained decision ready information GeoPackages with encrypted content should include the access policy that expresses — in a standardized fashion — the conditions for an application to decrypt and render the encrypted content. Further work should evaluate the latest work of the GeoXACML 3.0 standardization (see GeoXACML SWG for more details).
ANNEX A (INFORMATIVE) GEOPACKAGE DATA CENTRIC SECURITY EXTENSIONS
The Data Centric Security (DCS) work within OGC Testbed 17 results in two GeoPackage extensions: the first extension for storing encrypted Features and the second extension for storing encrypted Tiles. Either extension defines how encrypted data (features or tiles) and the associated decryption key as well as related metadata information can be stored.

The client implementation for reading and decrypting features and tiles was implemented by Compusult. The DCS GeoPackage Server was implemented by Secure Dimensions as a Geoserver plugin. The implementation allows to create a DCS GeoPackage leveraging OGC API Features and Tiles as well as OGC Web Feature Service 2.0.

## A.1. GeoPackage DCS Features Extension

### A.1.1. Extension Title

DCS-Features

### A.1.2. Introduction

This extension provides a mechanism for storing encrypted Features encoded in GeoJSON as JWE in a GeoPackage.

### A.1.3. Extension Author

Secure Dimensions GmbH, in collaboration with the participants of OGC Testbed-17, and the OGC Disaster Pilot 2021.
A.1.4. Extension Name or Template

sd_dcs_features (will become gpkg_dcs_features if adopted by the OGC)

A.1.5. Extension Type

New requirement dependent on GeoPackage Core (Clause 1).

A.1.6. Applicability

This extension allows to store Simple Features, encoded in GeoJSON, encrypted as JWE as defined in RFC 7516 — JSON Web Encryption (JWE). This extension does not constraint how the data is encrypted. It is outside the scope of this specification how the cipher key information is protected and securely communicated to the client application that is supposed to decrypt the data.

NOTE: For Testbed 17, a working prototype was implemented that is described in more detail in the Testbed 17 Data Centric Security ER.

A.1.7. Scope

read-write

A.1.8. Specification

A.1.8.1. gpkg_extensions

To use this extension, add the following rows to this table.

<table>
<thead>
<tr>
<th>TABLE_NAME</th>
<th>COLUMN_NAME</th>
<th>EXTENSION_NAME</th>
<th>DEFINITION</th>
<th>SCOPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>gpkgext_contents</td>
<td>data_type</td>
<td>sd_dcs_features</td>
<td>a reference to this file</td>
<td>read-write</td>
</tr>
<tr>
<td>gpkgext_dcs_layers</td>
<td>null</td>
<td>sd_dcs_features</td>
<td>a reference to this file</td>
<td>read-write</td>
</tr>
</tbody>
</table>

NOTE: The values in the definition column SHOULD refer in some human-readable way to this extension specification. If the extension is adopted by the OGC, it will gain the “gpkg_” prefix (replacing “sd_”) and get a different definition permalink.
**A.1.8.2. New Table Definitions**

Following are definitions of the tables for this extension.

As with other GeoPackage tables, this extension takes no position on how either of these tables are to be used by a client.

**A.1.8.2.1. sd_dcs_features_<identifier>**

This table contains encrypted features. The identifier is a string, uniquely representing the encrypted features stored in this table. The identifier may be an obfuscation of the actual feature type in cases where naming the table after the feature type might disclose sensitive information.

**NOTE 1:** For the Testbed 17 implementation, the identifier is a md5 hash of the feature type.

The columns of this table are:

- **fid** is a primary key
- **the_geom** is the bounding box of the encrypted feature or null in case it is withheld for sensitivity reasons
- **confidentiality** is a JSON Object describing the confidentiality labelling and additional information about the encrypted feature. The actual structure of the JSON is outside the scope of this specification
- **structure** is a GeoJSON based description of the structure of the feature type.
- **data** is the encrypted feature using compact JWE encoding

**NOTE 2:** The confidentiality and structure columns may contain JSON, JWS or JWE. The exact type is specified via the mime-type column in the gpkg_data_columns.

**A.1.8.2.2. gpkg_data_columns**

This table contains the information about the data type for the columns in the sd_dcs_features_<identifier> table.

To use this extension, add the following rows to this table.

Row 1: Definition of the data column

- **table_name** has the value sd_dcs_features_<identifier>
- **column_name** data
• name has the value sd_dcs_features_<identifier>-data
• title has value Encrypted Feature Data
• description description, e.g. The encrypted data of the feature using JWE compact encoding with symmetric cipher
• mime_type has value application/jose
• constraint_name has the value null

Row 2: Definition of the structure column
• table_name has the value sd_dcs_features_<identifier>
• column_name structure
• name has the value sd_dcs_features_<identifier>-structure
• title has value Feature Type Data
• description description, e.g. The feature type description represented as JSON, JWS or JWE
• mime_type has value application/json or application/jose to represent JWE or JWS encoded data
• constraint_name has the value null

Row 3: Definition of the confidentiality column
• table_name has the value sd_dcs_features_<identifier>
• column_name confidentiality
• name has the value sd_dcs_features_<identifier>-confidentiality
• title has value The confidentiality labelling and producer information
• description description, e.g. The confidentiality labelling and producer information encoded as JSON or JWS
• mime_type has value application/json or application/jose
• constraint_name has the value null

NOTE: No explicit media type exists for JWS or JWE encoded data. IANA media type “application/jose” must be used and from counting the dots, an application can defer whether the structure refers to JWS (2 dots) or JWE (4 dots). Some applications use the value “JWE” and “JWS” to determine between JWE and JWS encodings. For Testbed 17, the IANA media type “application/jose” was used.
A.2. GeoPackage DCS Tiles Extension

A.2.1. Extension Title

DCS-Tiles

A.2.2. Introduction

This extension provides a mechanism for storing encrypted Tiles and associated metadata such as integrity and confidentiality labelling in a GeoPackage.

A.2.3. Extension Author

Secure Dimensions GmbH, in collaboration with the participants of OGC Testbed-17, and the OGC Disaster Pilot 2021.

A.2.4. Extension Name or Template

sd_dcs_tiles (will become gpkg_dcs_tiles if adopted by the OGC)

A.2.5. Extension Type

New requirement dependent on GeoPackage Core (Clause 1).

A.2.6. Applicability

This extension allows to store encrypted binary image data (e.g. Tile) as a BLOB. This extension does not constraint how the data is encrypted. It is outside the scope of this specification how the cipher key information is protected and securely communicated to the client application that is supposed to decrypt the data.

This extension also defines the mechanism how to store cipher key information such that an application can decrypt the data.

To ensure tamper resistance of the encrypted tile data, an integrity check is stored that relates the data with the mandatory meta information zoom_level, tile_column, tile_row.
NOTE: For Testbed 17, a working prototype was implemented that is described in more detail in the Testbed 17 Data Centric Security ER.

A.2.7. Scope

read-write

A.2.8. Specification

A.2.8.1. gpkg_extensions

To use this extension, add the following rows to this table.

Table A.2 — gpkg_extensions Table Rows

<table>
<thead>
<tr>
<th>TABLE_NAME</th>
<th>COLUMN_NAME</th>
<th>EXTENSION_NAME</th>
<th>DEFINITION</th>
<th>SCOPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>gpkgext_contents</td>
<td>data_type</td>
<td>sd_dcs_tiles</td>
<td>a reference to this file</td>
<td>read-write</td>
</tr>
</tbody>
</table>

NOTE: The values in the definition column SHOULD refer in some human-readable way to this extension specification. If the extension is adopted by the OGC, it will gain the "gpkg_" prefix (replacing "sd_") and get a different definition permalink.

A.2.8.2. New Table Definitions

Following are definitions of the tables for this extension. As with other GeoPackage tables, this extension takes no position on how either of these tables are to be used by a client.

A.2.8.2.1. sd_dcs_tiles_<identifier>

This table contains encrypted tiles. The identifier is a string, uniquely representing the encrypted tile layer stored in this table. The identifier may be an obfuscation of the actual feature type in cases where naming the table after the feature type might disclose sensitive information.

NOTE: For the Testbed 17 implementation, the identifier is a md5 hash of the feature type.

The columns of this table are:

- id is a primary key
- zoom_level as specified by GeoPackage
• tile_column as specified by GeoPackage
• tile_row as specified by GeoPackage
• dcs_info is a JSON Object describing the confidentiality labelling and additional information about the encrypted feature. The actual structure of the JSON is outside the scope of this specification
• dek_info is a JWT defining the kid used for encryption. Also, the JWK payload contains additional information about the key origin such as issuer, creating application and user.
• tile_data is the encrypted tile using symmetric key encryption with the key described in dek_info column.

A.2.8.2.2. gpkg_data_columns

This table contains the information about the data type for the columns in the sd_dcs_tiles_<identifier> table.

To use this extension, add the following rows to this table.

Row 1: Definition of the tile_data column
• table_name has the value sd_dcs_tiles_<identifier>
• column_name tile_data
• name has the value sd_dcs_tiles_<identifier>-tile_data
• title has value Encrypted Tile Data
• description description, e.g. The encrypted data of the tile using symmetric cipher
• mime_type has value application/octet-stream
• constraint_name has the value null

Row 2: Definition of the dcs_info column
• table_name has the value sd_dcs_tiles_<identifier>
• column_name dcs_info
• name has the value sd_dcs_tiles_<identifier>-dcs_info
• title has value DCS Metadata
• description description, e.g. The tile description
• mime_type has value application/jose to represent JWE or JWS encoded data
• constraint_name has the value null

Row 3: Definition of the dek_info column
• table_name has the value sd_dcs_tiles_<identifier>
• column_name dek_info
• name has the value sd_dcs_tiles_<identifier>-dek_info
• title has value The information about the encryption key as JWT
• description description, e.g. The key can be fetched via kid or kurl
• mime_type has value application/jose
• constraint_name has the value null

NOTE: No explicit media type exists for JWS or JWE encoded data. IANA media type “application/jose” must be used and from counting the dots, an application can defer whether the structure refers to JWS (2 dots) or JWE (4 dots). Some applications use the value “JWE” and “JWS” to determine between JWE and JWS encodings. For Testbed 17, the IANA media type “application/jose” was used.
ANNEX B (INFORMATIVE) REVISION HISTORY
# ANNEX B

(INFORMATIVE)

REVISION HISTORY

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BIBLIOGRAPHY


