

MILE  
Internet-Draft  
Intended status: Standards Track  
Expires: June 2, 2019

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November 29, 2018

CBOR/JSON binding of IODEF  
draft-ietf-mile-jsoniodef-06

Abstract

RFC7970 specified an information model and a corresponding XML data model for exchanging incident and indicator information. This draft provides an alternative data model implementation in CBOR/JSON.

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## 1. Introduction

[RFC7970] defines a data representation for security incident reports and indicators commonly exchanged by operational security teams. It facilitates the automated exchange of this information to enable mitigation and watch-and-warning. Section 3 of [RFC7970] defined an information model using Unified Modeling Language (UML) and a corresponding Extensible Markup Language (XML) schema data model in Section 8. This UML-based information model and XML-based data model are referred to as IODEF UML and IODEF XML, respectively in this document.

This document defines an alternate implementation of the IODEF UML information model by specifying a JavaScript Object Notation (JSON) data model using CDDL and JSON Schema [jsonschema]. This JSON data model is referred to as IODEF JSON in this document.

IODEF JSON provides all of the expressivity of IODEF XML. It gives implementers and operators an alternative format to exchange the same information.

The normative IODEF JSON data model is found in Section 5. Section 2 and Section 3 describe the data types and elements of this data model. Section 4 provides examples.

### 1.1. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

## 2. IODEF Data Types

The abstract IODEF JSON implements the abstract data types specified in Section 2 of [RFC7970].

### 2.1. Abstract Data Type to JSON Data Type Mapping

IODEF JSON uses native and derived JSON data types. Figure 1 describes the mapping between the abstract data types in Section 2 of [RFC7970] and their corresponding implementations in IODEF JSON.

IODEF Data Type	[RFC7970] Reference	JSON Data Type
INTEGER	Section 2.1	"integer" per [jsonschema]
REAL	Section 2.2	"number" per [jsonschema]
CHARACTER	Section 2.3	"string" per [jsonschema]
STRING	Section 2.3	"string" per [jsonschema]
ML_STRING	Section 2.4	see Section 2.2.1
BYTE	Section 2.5.1	"string" per [jsonschema]
BYTE[ ]	Section 2.5.1	"string" per [jsonschema]
HEXBIN	Section 2.5.2	"string" per [jsonschema]
HEXBIN[ ]	Section 2.5.2	"string" per [jsonschema]
ENUM	Section 2.6	"enum" array per [jsonschema]
DATETIME	Section 2.7	"string" per [jsonschema]
TIMEZONE	Section 2.8	"string" per [jsonschema]
PORTLIST	Section 2.9	"string" per [jsonschema]
POSTAL	Section 2.10	ML_STRING, Section 2.2.1
PHONE	Section 2.11	"string" per [jsonschema]
EMAIL	Section 2.12	"string" per [jsonschema]
URL	Section 2.13	"string" per [jsonschema]
ID	Section 2.14	"string" per [jsonschema]
IDREF	Section 2.14	"string" per [jsonschema]
SOFTWARE	Section 2.15	see Section 2.2.2
STRUCTUREDINFO	[RFC 7203]	see Section 2.2.3
EXTENSION	Section 2.16	see Section 2.2.4

Figure 1: JSON Data Types

IODEF Data Type	CBOR Data Type	CDDL prelude [draft-ietf-cbor-cddl-05]
INTEGER	0, 1, 6 tag 2, 6 tag 3	integer
REAL	7 bits 26	float32
CHARACTER	3	text
STRING	3	text
ML_STRING	5	Maps/Structs (Section 3.5.1)
BYTE	6 tag 22	eb64legacy
BYTE[]	6 tag 22	eb64legacy
HEXBIN	2	bytes
HEXBIN[]	2	bytes
ENUM	-	Choices (Section 2.2.2)
DATETIME	6 tag 0	tdate
TIMEZONE	3	text
PORTLIST	3	text
POSTAL	3	ML_STRING (Section 2.2.1)
PHONE	3	text
EMAIL	3	text
URL	6 tag 32	uri
ID	3	text
IDREF	3	text
SOFTWARE	5	Maps/Structs (Section 3.5.1)
STRUCTUREDINFO	5	Maps/Structs (Section 3.5.1)
EXTENSION	5	Maps/Structs (Section 3.5.1)

Figure 2: CBOR Data Types

## 2.2. Complex JSON Types

### 2.2.1. Multilingual Strings

A string that needs to be represented in a human-readable language different from the default encoding of the document is represented in the information model by the ML\_STRING data type. This data type is implemented as either an object with "value", "lang", and "translation-id" elements or a text string as defined in Section 5. Examples are shown below.

```
"MLStringType": {
  "value": "free-form text",           //STRING
  "lang": "en",                       //ENUM
  "translation-id": "jp2en0023"       //STRING
}
```

### 2.2.2. Software and Software Reference

A particular version of software is represented in the information model by the SOFTWARE data type. This software can be described by using a reference, a URL, or with free-form text. The SOFTWARE data type is implemented as an object with "SoftwareReference", "URL", and "Description" elements as defined in Section 5. Examples are shown below.

```
"SoftwareType": {
  "SoftwareReference": {...},           //SoftwareReference
  "Description": ["MS Windows"]        //STRING
}
```

SoftwareReference class is a reference to a particular version of software. Examples are shown below.

```
"SoftwareReference": {
  "value": "cpe:/a:google:chrome:59.0.3071.115 ", //STRING
  "spec-name": "cpe",                             //ENUM
  "dtype": "string",                               //ENUM
}
```

### 2.2.3. Structured Information

Information provided in a form of structured string, such as ID, or structured information, such as XML documents, is represented in the information model by the STRUCTUREDINFO data type. Note that this type was originally specified in [RFC7203]. The STRUCTUREDINFO data type is implemented as an object with "SpecID", "ext-SpecID", "ContentID", "dtype", "RawData", "Reference" elements. An example for embedding a structured ID is shown below.

```
"StructuredInfo": {
  "SpecID": "cve",                               //ENUM
  "ContentID": "CVE-2007-5000"                   //STRING
}
```

When embedding the raw data, base64 conversion should be used for encoding the data, as shown below.

```
"StructuredInfo": {
  "SpecID": "oval",                               //ENUM
  "RawData": "<<<strings encoded with base64>>>" //BYTE
}
```

#### 2.2.4. EXTENSION

Information not otherwise represented in the IODEF can be added using the EXTENSION data type. This data type is a generic extension mechanism. The EXTENSION data type is implemented as an ExtensionType object with "value", "name", "dtype", "ext-dtype", "meaning", "formatid", "restriction", "ext-restriction", and "observable-id" elements. An example for embedding a structured ID is shown below.

```
"ExtensionType": {
  "value": "xxxxxxx",           //String
  "name": "Syslog",             //String
  "dtype": "string",            //ENUM
  "meaning": "Syslog from the security appliance X", //String
}
```

### 3. IODEF JSON Data Model

#### 3.1. Classes and Elements

The following table shows the list of IODEF Classes, their elements, and the corresponding section in [RFC7970]. Note that the complete JSON schema is defined in Section 5 using CDDL.

IODEF Class	Class Elements and Attribute	Corresponding Section in [RFC7970]
IODEF-Document	version lang? format-id? private-enum-name? private-enum-id? Incident+ AdditionalData*	3.1
Incident	purpose ext-purpose? status? ext-status? lang? restriction? ext-restriction? observable-id? IncidentID AlternativeID?	3.2

	RelatedActivity* DetectTime? StartTime? EndTime? RecoveryTime? ReportTime? GenerationTime Description* Discovery* Assessment* Method* Contact+ EventData* Indicator* History? AdditionalData*	
IncidentID	id name instance? restriction? ext-restriction?	3.4
AlternativeID	restriction? ext-restriction? IncidentID+	3.5
RelatedActivity	restriction? ext-restriction? IncidentID* URL* ThreatActor* Campaign* IndicatorID* Confidence? Description* AdditionalData*	3.6
ThreatActor	restriction? ext-restriction? ThreatActorID* URL* Description* AdditionalData*	3.7
Campaign	restriction? ext-restriction? CampaignID*	



	URL* Description* AdditionalData*	3.8
Contact	role ext-role? type ext-type? restriction? ext-restriction? ContactName*, ContactTitle* Description* RegistryHandle* PostalAddress* Email* Telephone* Timezone? Contact* AdditionalData*	3.9
RegistryHandle	handle registry ext-registry?	3.9.1
PostalAddress	type? ext-type? PAddress Description*	3.9.2
Email	type? ext-type? EmailTo Description*	3.9.3
Telephone	type? ext-type? TelephoneNumber Description*	3.9.4
Discovery	source? ext-source? restriction? ext-restriction? Description* Contact* DetectionPattern*	3.10

DetectionPattern	restriction? ext-restriction? observable-id? Application Description* DetectionConfiguration*	3.10.1
Method	restriction? ext-restriction? Reference* Description* AttackPattern* Vulnerability* Weakness* AdditionalData*	3.11
Reference	observable-id? ReferenceName? URL* Description*	3.11.1
Assessment	occurence? restriction? ext-restriction? observable-id? IncidentCategory* SystemImpact* BusinessImpact* TimeImpact* MonetaryImpact* IntendedImpact* Counter* MitigatingFactor* Cause* Confidence? AdditionalData*	3.12
SystemImpact	severity? completion? type ext-type? Description*	3.12.1
BusinessImpact	severity? ext-severity? type ext-type? Description*	3.12.2

TimeImpact	value severity? metric ext-metric? duration? ext-duration?	3.12.3
MonetaryImpact	value severity? currency?	3.12.4
Confidence	value rating ext-rating?	3.12.5
History	restriction? ext-restriction? HistoryItem+	3.13
HistoryItem	action ext-action? restriction? ext-restriction? observable-id? DateTime IncidentID? Contact? Description* DefinedCOA* AdditionalData*	3.13.1
EventData	restriction? ext-restriction? observable-id? Description* DetectTime? StartTime? EndTime? RecoveryTime? ReportTime? Contact* Discovery* Assessment? Method* System* Expectation* RecordData*	

	EventData* AdditionalData*	3.14
Expectation	action? ext-action? severity? restriction? ext-restriction? observable-id? Description* DefinedCOA* StartTime? EndTime? Contact?	3.15
System	category? ext-category? interface? spoofed? virtual? ownership? ext-ownership? restriction? ext-restriction? Node NodeRole* Service* OperatingSystem* Counter* AssetID* Description* AdditionalData*	3.16
Node	DomainData* Address* PostalAddress? Location* Counter*	3.17
Address	value category ext-category? vlan-name? vlan-num? observable-id?	3.17.1
NodeRole	category ext-category?	

	Description*	3.17.2
Counter	value type ext-type? unit ext-unit? meaning? duration? ext-duration?	3.17.3
DomainData	system-status ext-system-status? domain-status ext-domain-status? observable-id? Name DateDomainWasChecked? RegistrationDate? ExpirationDate? RelatedDNS* Nameservers* DomainContacts?	3.18
Nameserver	Server Address*	3.18.1
DomainContacts	SameDomainContact? Contact+	3.18.2
Service	ip-protocol? observable-id? ServiceName? Port? Portlist? ProtoCode? ProtoType? ProtoField? ApplicationHeaderField* EmailData? Application?	3.19
ServiceName	IANAService? URL* Description*	3.19.1
EmailData	observable-id? EmailTo*	

	EmailFrom? EmailSubject? EmailX-Mailer? EmailHeaderField* EmailHeaders? EmailBody? EmailMessage? HashData* Signature*	3.19.2
RecordData	restriction? ext-restriction? observable-id? DateTime? Description* Application? RecordPattern* RecordItem* URL* FileData* WindowsRegistryKeysModified* CertificateData* AdditionalData*	3.19.3
RecordPattern	type ext-type? offset? offsetunit? ext-offsetunit? instance? value	3.19.4
WindowsRegistryKeysModified	observable-id? Key+	3.20
Key	registryaction? ext-registryaction? observable-id? KeyName KeyValue?	3.20.1
CertificateData	restriction? ext-restriction? observable-id? Certificate+	3.21
Certificate	observable-id? X509Data	

	Description*	3.21.1
FileData	restriction? ext-restriction? observable-id? File+	3.22
File	observable-id? FileName? FileSize? FileType? URL* HashData? Signature* AssociatedSoftware? FileProperties*	3.22.1
HashData	scope HashTargetID? Hash* FuzzyHash*	3.23
Hash	DigestMethod DigestValue CanonicalizationMethod? Application?	3.23.1
FuzzyHash	FuzzyHashValue+ Application? AdditionalData*	3.23.2
Indicator	restriction? ext-restriction? IndicatorID AlternativeIndicatorID* Description* StartTime? EndTime? Confidence? Contact* Observable? uid-ref? IndicatorExpression? IndicatorReference? NodeRole* AttackPhase* Reference* AdditionalData*	3.24

IndicatorID	id name version	3.24.1
AlternativeIndicatorID	restriction? ext-restriction? IndicatorReference+	3.24.2
Observable	restriction? ext-restriction? System? Address? DomainData? Service? EmailData? WindowsRegistryKeysModified? FileData? CertificateData? RegistryHandle? RecordData? EventData? Incident? Expectation? Reference? Assessment? DetectionPattern? HistoryItem? BulkObservable? AdditionalData*	3.24.3
BulkObservable	type? ext-type? BulkObservableFormat? BulkObservableList AdditionalData*	3.24.4
BulkObservableFormat	Hash? AdditionalData*	3.24.5
IndicatorExpression	operator? ext-operator? IndicatorExpression* Observable* uid-ref* IndicatorReference* Confidence? AdditionalData*	3.24.6



IndicatorReference	uid-ref? euid-ref? version?	3.24.7
AttackPhase	AttackPhaseID* URL* Description* AdditionalData*	3.24.8

### IODEF Classes

#### 3.2. Mapping between CBOR/JSON and XML IODEF

- o This document treats attributes and elements of each class defined in [RFC7970] equally and is agnostic on the order of their appearances.
- o Flow class is deleted, and classes with its instances now directly have instances of EventData class that used to belong to the Flow class.
- o ApplicationHeader class is deleted, and classes with its instances now directly have instances of ApplicationHeaderField class that used to belong to the ApplicationHeader class.
- o SignatureData class is deleted, and classes with its instances now directly have instance of Signature class that used to belong to the SignatureData class.
- o IndicatorData class is deleted, and classes with its instances now directly have the instances of Indicator class that used to belong to the IndicatorData class.
- o ObservableReference class is deleted, and classes with its instances now directly have uid-ref as an element.
- o Record class is replaced by RecordData class, and RecordData class is renamed to Record class.
- o Record class is deleted, and classes with its instances now directly have the instances of RecordData class that used to belong to the Record class.
- o The MLStringType were modified to support simple string by allowing the type to have not only a predefined object type but

also text type, in order to allow simple descriptions of elements of the type.

- o The elements of ML\_STRING type in XML IODEF document are presented as either STRING type or ML\_STRING type in CBOR/JSON IODEF document.
- o Data models of the extension classes defined by [RFC7203] and referenced by [RFC7970] are represented by StructuredInfo class defined in this document.
- o The order of appearances of class elements were ignored in CBOR/JSON version.

#### 4. Examples

This section provides example of IODEF documents. These examples do not represent the full capabilities of the data model or the the only way to encode particular information.

##### 4.1. Minimal Example

A document containing only the mandatory elements and attributes is shown below in JSON and CBOR, respectively.

```
{
  "version": "2.0",
  "lang": "en",
  "Incident": [{
    "purpose": "reporting",
    "restriction": "private",
    "IncidentID": {
      "id": "492382",
      "name": "csirt.example.com"
    },
    "GenerationTime": "2015-07-18T09:00:00-05:00",
    "Contact": [{
      "type": "organization",
      "role": "creator",
      "Email": [{"EmailTo": "contact@csirt.example.com"}]
    }]
  }]
}
```

Figure 3: A Minimal Example in JSON

```
A3                                     # map(3)
67                                     # text(7)
```

```

    76657273696F6E      # "version"
63      322E30          # text(3)
    322E30              # "2.0"
64      6C616E67        # text(4)
    6C616E67            # "lang"
62      656E            # text(2)
    656E                # "en"
68      496E636964656E74 # text(8)
    496E636964656E74   # "Incident"
81      # array(1)
    A5                  # map(5)
    67                  # text(7)
    707572706F7365      # "purpose"
    69                  # text(9)
    7265706F7274696E67  # "reporting"
    6B                  # text(11)
    7265737472696374696F6E # "restriction"
    67                  # text(7)
    70726976617465      # "private"
    6A                  # text(10)
    496E636964656E744944 # "IncidentID"
    A2                  # map(2)
    62                  # text(2)
    6964                # "id"
    66                  # text(6)
    343932333832        # "492382"
    64                  # text(4)
    6E616D65            # "name"
    71                  # text(17)
    63736972742E6578616D706C652E636F6D # "csirt.example.com"
    6E                  # text(14)
    47656E65726174696F6E54696D65      # "GenerationTime"
    C0                  # tag(0)
    78 19              # text(25)
    323031352D30372D31385430393A30303A30302D30353A3030
    # "2015-07-18T09:00:00-05:00"
    67                  # text(7)
    436F6E74616374      # "Contact"
    81                  # array(1)
    A3                  # map(3)
    64                  # text(4)
    74797065            # "type"
    6C                  # text(12)
    6F7267616E697A6174696F6E          # "organization"
    64                  # text(4)
    726F6C65            # "role"
    67                  # text(7)
    63726561746F72      # "creator"

```

```

65                                     # text(5)
  456D61696C                         # "Email"
81                                     # array(1)
  A1                                   # map(1)
    67                               # text(7)
      456D61696C546F                 # "EmailTo"
    78 19                             # text(25)
      636F6E746163744063736972742E6578616D706C652E636F6D
                                     # "contact@csirt.example.com"

```

Figure 4: A Minimal Example in CBOR

#### 4.2. Indicators from a Campaign

An example of C2 domains from a given campaign is shown below in JSON and CBOR, respectively.

```

{
  "version": "2.0",
  "lang": "en",
  "Incident": [{
    "purpose": "watch",
    "restriction": "green",
    "IncidentID": {
      "id": "897923",
      "name": "csirt.example.com"
    }
  ]},
  "RelatedActivity": [{
    "ThreatActor": [{
      "ThreatActorID": ["TA-12-AGGRESSIVE-BUTTERFLY"],
      "Description": ["Aggressive Butterfly"]}],
    "Campaign": [{
      "CampaignID": ["C-2015-59405"],
      "Description": ["Orange Giraffe"]
    }]
  }],
  "GenerationTime": "2015-10-02T11:18:00-05:00",
  "Description": ["Summarizes the Indicators of Compromise for the
    Orange Giraffe campaign of the Aggressive Butterfly crime gang."],
  "Assessment": [{
    "Impact": [{"BusinessImpact": {"type": "breach-proprietary"}}]
  }],
  "Contact": [{
    "type": "organization",
    "role": "creator",
    "ContactName": ["CSIRT for example.com"],
    "Email": [{

```

```

    "EmailTo": "contact@csirt.example.com"
  }
},
"Indicator": [{
  "IndicatorID": {
    "id": "G90823490",
    "name": "csirt.example.com",
    "version": "1"
  },
  "Description": ["C2 domains"],
  "StartTime": "2014-12-02T11:18:00-05:00",
  "Observable": {
    "BulkObservable": {
      "type": "ipv6-addr",
      "BulkObservableList": "kj290023j09r34.example.com"
    }
  }
}]
}]
}

```

Figure 5: Indicators from a Campaign in JSON

```

A3                                     # map(3)
67                                     # text(7)
  76657273696F6E                       # "version"
63                                     # text(3)
  322E30                               # "2.0"
64                                     # text(4)
  6C616E67                             # "lang"
62                                     # text(2)
  656E                                 # "en"
68                                     # text(8)
  496E636964656E74                   # "Incident"
81                                     # array(1)
  A9                                   # map(9)
    67                                 # text(7)
      707572706F7365                 # "purpose"
    65                                 # text(5)
      7761746368                     # "watch"
    6B                                 # text(11)
      7265737472696374696F6E         # "restriction"
    65                                 # text(5)
      677265656E                     # "green"
    6A                                 # text(10)
      496E636964656E744944           # "IncidentID"
  A2                                   # map(2)
    62                                 # text(2)
      6964                           # "id"

```

```
66          # text(6)
383937393233      # "897923"
64          # text(4)
6E616D65          # "name"
71          # text(17)
63736972742E6578616D706C652E636F6D # "csirt.example.com"
6F          # text(15)
52656C617465644163746976697479 # "RelatedActivity"
81          # array(1)
A2          # map(2)
6B          # text(11)
5468726561744163746F72      # "ThreatActor"
81          # array(1)
A2          # map(2)
6D          # text(13)
5468726561744163746F724944 # "ThreatActorID"
81          # array(1)
78 1A          # text(26)
54412D31322D414747524553534956452D425554544552464
C59          # "TA-12-AGGRESSIVE-BUTTERFLY"
6B          # text(11)
4465736372697074696F6E      # "Description"
81          # array(1)
74          # text(20)
4167677265737369766520427574746572666C79
          # "Aggressive Butterfly"
68          # text(8)
43616D706169676E          # "Campaign"
81          # array(1)
A2          # map(2)
6A          # text(10)
43616D706169676E4944 # "CampaignID"
81          # array(1)
6C          # text(12)
432D323031352D3539343035 # "C-2015-59405"
6B          # text(11)
4465736372697074696F6E      # "Description"
81          # array(1)
6E          # text(14)
4F72616E67652047697261666665 # "Orange Giraffe"
6E          # text(14)
47656E65726174696F6E54696D65 # "GenerationTime"
C0          # tag(0)
78 19          # text(25)
323031352D31302D30325431313A31383A30302D30353A3030
          # "2015-10-02T11:18:00-05:00"
6B          # text(11)
4465736372697074696F6E      # "Description"
```

```

81                                # array(1)
78 6F                            # text(111)
53756D6D6172697A65732074686520496E64696361746F7273206F6620436
F6D70726F6D69736520666F7220746865204F72616E676520476972616666
652063616D706169676E206F6620746865204167677265737369766520427
574746572666C79206372696D652067616E672E
# "Summarizes the Indicators of Compromise for the Orange
  Giraffe campaign of the Aggressive Butterfly crime gang."
6A                                # text(10)
4173736573736D656E74            # "Assessment"
81                                # array(1)
A1                                # map(1)
66                                # text(6)
496D70616374                    # "Impact"
81                                # array(1)
A1                                # map(1)
6E                                # text(14)
427573696E657373496D70616374 # "BusinessImpact"
A1                                # map(1)
64                                # text(4)
74797065                        # "type"
72                                # text(18)
6272656163682D70726F7072696574617279
# "breach-proprietary"
67                                # text(7)
436F6E74616374                # "Contact"
81                                # array(1)
A4                                # map(4)
64                                # text(4)
74797065                        # "type"
6C                                # text(12)
6F7267616E697A6174696F6E      # "organization"
64                                # text(4)
726F6C65                        # "role"
67                                # text(7)
63726561746F72                # "creator"
6B                                # text(11)
436F6E746163744E616D65        # "ContactName"
81                                # array(1)
75                                # text(21)
435349525420666F72206578616D706C652E636F6D
# "CSIRT for example.com"
65                                # text(5)
456D61696C                      # "Email"
81                                # array(1)
A1                                # map(1)
67                                # text(7)
456D61696C546F                # "EmailTo"

```

```
78 19 # text(25)
636F6E746163744063736972742E6578616D706C652E636F6D
# "contact@csirt.example.com"
69 # text(9)
496E64696361746F72 # "Indicator"
81 # array(1)
A4 # map(4)
6B # text(11)
496E64696361746F724944 # "IndicatorID"
A3 # map(3)
62 # text(2)
6964 # "id"
69 # text(9)
473930383233343930 # "G90823490"
64 # text(4)
6E616D65 # "name"
71 # text(17)
63736972742E6578616D706C652E636F6D
# "csirt.example.com"
67 # text(7)
76657273696F6E # "version"
61 # text(1)
31 # "1"
6B # text(11)
4465736372697074696F6E # "Description"
81 # array(1)
6A # text(10)
433220646F6D61696E73 # "C2 domains"
69 # text(9)
537461727454696D65 # "StartTime"
C0 # tag(0)
78 19 # text(25)
323031342D31322D30325431313A31383A30302D30353A3030
# "2014-12-02T11:18:00-05:00"
6A # text(10)
4F627365727661626C65 # "Observable"
A1 # map(1)
6E # text(14)
42756C6B4F627365727661626C65 # "BulkObservable"
A2 # map(2)
64 # text(4)
74797065 # "type"
69 # text(9)
697076362D61646472 # "ipv6-addr"
72 # text(18)
42756C6B4F627365727661626C654C697374
# "BulkObservableList"
78 1A # text(26)
```



```

6B6A3239303032336A30397233342E6578616D706C652E636F6D
# "kj290023j09r34.example.com"

```

Figure 6: Indicators from a Campaign in CBOR

## 5. The IODEF Data Model (CDDL)

```

start = iodef

;;; iodef.json: IODEF-Document

iodef = {
  version: text
  ? lang: lang
  ? format-id: text
  ? private-enum-name: text
  ? private-enum-id: text
  Incident: [+ Incident]
  ? AdditionalData: [+ ExtensionType]
}

duration = "second" / "minute" / "hour" / "day" / "month" / "quarter" /
           "year" / "ext-value"
lang = "" / text .regexp "[a-zA-Z]{1,8}(-[a-zA-Z0-9]{1,8})*"

restriction = "public" / "partner" / "need-to-know" / "private" /
              "default" / "white" / "green" / "amber" / "red" /
              "ext-value"

SpecID = "urn:ietf:params:xml:ns:mile:mmdef:1.2" / "private"
IDtype = text .regexp "[a-zA-Z_][a-zA-Z0-9_.-]*"
IDREFType = IDtype
URLtype = uri
TimeZonetype = text .regexp "Z|([+|-](0[0-9]|1[0-4]):[0-5][0-9])"
PortlistType = text .regexp "\\d+(\\-\\d+)?(,\\d+(\\-\\d+)?)*"
action = "nothing" / "contact-source-site" / "contact-target-site" /
         "contact-sender" / "investigate" / "block-host" /
         "block-network" / "block-port" / "rate-limit-host" /
         "rate-limit-network" / "rate-limit-port" / "redirect-traffic" /
         "honeypot" / "upgrade-software" / "rebuild-asset" /
         "harden-asset" / "remediate-other" / "status-triage" /
         "status-new-info" / "watch-and-report" / "training" /
         "defined-coa" / "other" / "ext-value"

DATETIME = tdate

BYTE = eb64legacy

MLStringType = {

```

```
    value: text
    ? lang: lang
    ? translation-id: text
} / text
```

```
PositiveFloatType = float32 .gt 0
```

```
PAddressType = MLStringType
```

```
ExtensionType = {
  value: text
  ? name: text
  dtype: "boolean" / "byte" / "bytes" / "character" / "date-time" /
        "ntpstamp" / "integer" / "portlist" / "real" / "string" /
        "file" / "path" / "frame" / "packet" / "ipv4-packet" / "json" /
        "ipv6-packet" / "url" / "csv" / "winreg" / "xml" / "ext-value"
        .default "string"
  ? ext-dtype: text
  ? meaning: text
  ? formatid: text
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  ? observable-id: IDtype
}
```

```
SoftwareType = {
  ? SoftwareReference: SoftwareReference
  ? URL: [+ URLtype]
  ? Description: [+ MLStringType]
}
```

```
SoftwareReference = {
  ? value: text
  spec-name: "custom" / "cpe" / "swid" / "ext-value"
  ? ext-spec-name: text
  ? dtype: "bytes" / "integer" / "real" / "string" / "xml" / "ext-value"
        .default "string"
  ? ext-dtype: text
}
```

```
Incident = {
  purpose: "traceback" / "mitigation" / "reporting" / "watch" / "other" /
        "ext-value"
  ? ext-purpose: text
  ? status: "new" / "in-progress" / "forwarded" / "resolved" / "future" /
        "ext-value"
  ? ext-status: text
  ? lang: lang
}
```

```
? restriction: restriction .default "private"
? ext-restriction: text
? observable-id: IDtype
IncidentID: IncidentID
? AlternativeID: AlternativeID
? RelatedActivity: [+ RelatedActivity]
? DetectTime: DATETIME
? StartTime: DATETIME
? EndTime: DATETIME
? RecoveryTime: DATETIME
? ReportTime: DATETIME
GenerationTime: DATETIME
? Description: [+ MLStringType]
? Discovery: [+ Discovery]
? Assessment: [+ Assessment]
? Method: [+ Method]
Contact: [+ Contact]
? EventData: [+ EventData]
? Indicator: [+ Indicator]
? History: History
? AdditionalData: [+ ExtensionType]
}
```

```
IncidentID = {
  id: text
  name: text
  ? instance: text
  ? restriction: restriction .default "private"
  ? ext-restriction: text
}
```

```
AlternativeID = {
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  IncidentID: [+ IncidentID]
}
```

```
RelatedActivity = {
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  ? IncidentID: [+ IncidentID]
  ? URL: [+ URLtype]
  ? ThreatActor: [+ ThreatActor]
  ? Campaign: [+ Campaign]
  ? IndicatorID: [+ IndicatorID]
  ? Confidence: Confidence
  ? Description: [+ text]
  ? AdditionalData: [+ ExtensionType]
```

```
}

ThreatActor = {
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  ? ThreatActorID: [+ text]
  ? URL: [+ URLtype]
  ? Description: [+ MLStringType]
  ? AdditionalData: [+ ExtensionType]
}

Campaign = {
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  ? CampaignID: [+ text]
  ? URL: [+ URLtype]
  ? Description: [+ MLStringType]
  ? AdditionalData: [+ ExtensionType]
}

Contact = {
  role: "creator" / "reporter" / "admin" / "tech" / "provider" / "user" /
    "billing" / "legal" / "irt" / "abuse" / "cc" / "cc-irt" / "leo" /
    "vendor" / "vendor-support" / "victim" / "victim-notified" /
    "ext-value"
  ? ext-role: text
  type: "person" / "organization" / "ext-value"
  ? ext-type: text
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  ? ContactName: [+ MLStringType]
  ? ContactTitle: [+ MLStringType]
  ? Description: [+ MLStringType]
  ? RegistryHandle: [+ RegistryHandle]
  ? PostalAddress: [+ PostalAddress]
  ? Email: [+ Email]
  ? Telephone: [+ Telephone]
  ? Timezone: TimeZonetype
  ? Contact: [+ Contact]
  ? AdditionalData: [+ ExtensionType]
}

RegistryHandle = {
  handle: text
  registry: "internic" / "apnic" / "arin" / "lacnic" / "ripe" /
    "afrinic" / "local" / "ext-value"
  ? ext-registry: text
}
```

```
PostalAddress = {
  ? type: "street" / "mailing" / "ext-value"
  ? ext-type: text
  PAddress: PAddressType
  ? Description: [+ MLStringType]
}

Email = {
  ? type: "direct" / "hotline" / "ext-value"
  ? ext-type: text
  EmailTo: text
  ? Description: [+ MLStringType]
}

Telephone = {
  ? type: "wired" / "mobile" / "fax" / "hotline" / "ext-value"
  ? ext-type: text
  TelephoneNumber: text
  ? Description: [+ MLStringType]
}

Discovery = {
  ? source: "nidps" / "hips" / "siem" / "av" / "third-party-monitoring" /
    "incident" / "os-log" / "application-log" / "device-log" /
    "network-flow" / "passive-dns" / "investigation" / "audit" /
    "internal-notification" / "external-notification" /
    "leo" / "partner" / "actor" / "unknown" / "ext-value"
  ? ext-source: text
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  ? Description: [+ MLStringType]
  ? Contact: [+ Contact]
  ? DetectionPattern: [+ DetectionPattern]
}

DetectionPattern = {
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  ? observable-id: IDtype
  Application: SoftwareType
  ? Description: [+ MLStringType]
  ? DetectionConfiguration: [+ text]
}

Method = {
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  ? Reference: [+ Reference]
```

```
? Description: [+ MLStringType]
? AttackPattern: [+ StructuredInfo]
? Vulnerability: [+ StructuredInfo]
? Weakness: [+ StructuredInfo]
? AdditionalData: [+ ExtensionType]
}

StructuredInfo = {
  SpecID: SpecID
  ? ext-SpecID: text
  ? ContentID: text
  ? (RawData: [+ BYTE] // Reference:[+ Reference])
  ? Platform:[+ Platform]
  ? Scoring:[+ Scoring]
}

Platform = {
  SpecID: SpecID
  ? ext-SpecID: text
  ? ContentID: text
  ? RawData: [+ BYTE]
  ? Reference: [+ Reference]
}

Scoring = {
  SpecID: SpecID
  ? ext-SpecID: text
  ? ContentID: text
  ? RawData: [+ BYTE]
  ? Reference: [+ Reference]
}

Reference = {
  ? observable-id: IDtype
  ? ReferenceName: ReferenceName
  ? URL: [+ URLtype]
  ? Description: [+ MLStringType]
}

ReferenceName = {
  specIndex: integer
  ID: IDtype
}

Assessment = {
  ? occurrence: "actual" / "potential"
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  ? observable-id: IDtype
  ? IncidentCategory: [+ MLStringType]
```

```
Impact: [+ {SystemImpact: SystemImpact} /
           {BusinessImpact: BusinessImpact} / {TimeImpact: TimeImpact} /
           {MonetaryImpact: MonetaryImpact} /
           {IntendedImpact: BusinessImpact}]
? Counter: [+ Counter]
? MitigatingFactor: [+ MLStringType]
? Cause: [+ MLStringType]
? Confidence: Confidence
? AdditionalData: [+ ExtensionType]
}

SystemImpact = {
? severity: "low" / "medium" / "high"
? completion: "failed" / "succeeded"
type: "takeover-account" / "takeover-service" / "takeover-system" /
      "cps-manipulation" / "cps-damage" / "availability-data" /
      "availability-account" / "availability-service" /
      "availability-system" / "damaged-system" / "damaged-data" /
      "breach-proprietary" / "breach-privacy" / "breach-credential" /
      "breach-configuration" / "integrity-data" /
      "integrity-configuration" / "integrity-hardware" /
      "traffic-redirection" / "monitoring-traffic" / "monitoring-host" /
      "policy" / "unknown" / "ext-value" .default "unknown"
? ext-type: text
? Description: [+ MLStringType]
}

BusinessImpact = {
? severity: "none" / "low" / "medium" / "high" / "unknown" / "ext-value"
           .default "unknown"
? ext-severity: text
type: "breach-proprietary" / "breach-privacy" / "breach-credential" /
      "loss-of-integrity" / "loss-of-service" / "theft-financial" /
      "theft-service" / "degraded-reputation" / "asset-damage" /
      "asset-manipulation" / "legal" / "extortion" / "unknown" /
      "ext-value" .default "unknown"
? ext-type: text
? Description: [+ MLStringType]
}

TimeImpact = {
value: PositiveFloatType
? severity: "low" / "medium" / "high"
metric: "labor" / "elapsed" / "downtime" / "ext-value"
? ext-metric: text
? duration: duration .default "hour"
? ext-duration: text
}
```

```
MonetaryImpact = {
  value: PositiveFloatType
  ? severity: "low" / "medium" / "high"
  ? currency: text
}

Confidence = {
  value: float32
  rating: "low" / "medium" / "high" / "numeric" / "unknown" / "ext-value"
  ? ext-rating: text
}

History = {
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  HistoryItem: [+ HistoryItem]
}

HistoryItem = {
  action: action .default "other"
  ? ext-action: text
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  ? observable-id: IDtype
  DateTime: DATETIME
  ? IncidentID: IncidentID
  ? Contact: Contact
  ? Description: [+ MLStringType]
  ? DefinedCOA: [+ text]
  ? AdditionalData: [+ ExtensionType]
}

EventData = {
  ? restriction: restriction .default "default"
  ? ext-restriction: text
  ? observable-id: IDtype
  ? Description: [+ MLStringType]
  ? DetectTime: DATETIME
  ? StartTime: DATETIME
  ? EndTime: DATETIME
  ? RecoveryTime: DATETIME
  ? ReportTime: DATETIME
  ? Contact: [+ Contact]
  ? Discovery: [+ Discovery]
  ? Assessment: Assessment
  ? Method: [+ Method]
  ? System: [+ System]
  ? Expectation: [+ Expectation]
```



```
? RecordData: [+ RecordData]
? EventData: [+ EventData]
? AdditionalData: [+ ExtensionType]
}
```

```
Expectation = {
  ? action: action .default "other"
  ? ext-action: text
  ? severity: "low" / "medium" / "high"
  ? restriction: restriction .default "default"
  ? ext-restriction: text
  ? observable-id: IDtype
  ? Description: [+ MLStringType]
  ? DefinedCOA: [+ text]
  ? StartTime: DATETIME
  ? EndTime: DATETIME
  ? Contact: Contact
}
```

```
System = {
  ? category: "source" / "target" / "intermediate" / "sensor" /
    "infrastructure" / "ext-value"
  ? ext-category: text
  ? interface: text
  ? spoofed: "unknown" / "yes" / "no" .default "unknown"
  ? virtual: "yes" / "no" / "unknown" .default "unknown"
  ? ownership: "organization" / "personal" / "partner" / "customer" /
    "no-relationship" / "unknown" / "ext-value"
  ? ext-ownership: text
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  ? observable-id: IDtype
Node: Node
  ? NodeRole: [+ NodeRole]
  ? Service: [+ Service]
  ? OperatingSystem: [+ SoftwareType]
  ? Counter: [+ Counter]
  ? AssetID: [+ text]
  ? Description: [+ MLStringType]
  ? AdditionalData: [+ ExtensionType]
}
```

```
Node = {
  (DomainData:[+ DomainData]
  ? Address:[+ Address] //
  ? DomainData:[+ DomainData]
  Address:[+ Address])
  ? PostalAddress: PostalAddress
```

```
? Location: [+ MLStringType]
? Counter: [+ Counter]
}
```

```
Address = {
  value: text
  category: "asn" / "atm" / "e-mail" / "ipv4-addr" / "ipv4-net" /
    "ipv4-net-masked" / "ipv4-net-mask" / "ipv6-addr" /
    "ipv6-net" / "ipv6-net-masked" / "mac" / "site-uri" /
    "ext-value" .default "ipv6-addr"
  ? ext-category: text
  ? vlan-name: text
  ? vlan-num: integer
  ? observable-id: IDtype
}
```

```
NodeRole = {
  category: "client" / "client-enterprise" / "client-partner" /
    "client-remote" / "client-kiosk" / "client-mobile" /
    "server-internal" / "server-public" / "www" / "mail" /
    "webmail" / "messaging" / "streaming" / "voice" / "file" /
    "ftp" / "p2p" / "name" / "directory" / "credential" /
    "print" / "application" / "database" / "backup" / "dhcp" /
    "assessment" / "source-control" / "config-management" /
    "monitoring" / "infra" / "infra-firewall" / "infra-router" /
    "infra-switch" / "camera" / "proxy" / "remote-access" /
    "log" / "virtualization" / "pos" / "scada" /
    "scada-supervisory" / "sinkhole" / "honeypot" /
    "anonymization" / "c2-server" / "malware-distribution" /
    "drop-server" / "hop-point" / "reflector" /
    "phishing-site" / "spear-phishing-site" / "recruiting-site" /
    "fraudulent-site" / "ext-value"
  ? ext-category: text
  ? Description: [+ MLStringType]
}
```

```
Counter = {
  value: float32
  type: "count" / "peak" / "average" / "ext-value"
  ? ext-type: text
  unit: "byte" / "mbit" / "packet" / "flow" / "session" / "alert" /
    "message" / "event" / "host" / "site" / "organization" /
    "ext-value"
  ? ext-unit: text
  ? meaning: text
  ? duration: duration .default "hour"
  ? ext-duration: text
}
```

```
DomainData = {
  system-status: "spoofed" / "fraudulent" / "innocent-hacked" /
    "innocent-hijacked" / "unknown" / "ext-value"
  ? ext-system-status: text
  domain-status: "reservedDelegation" / "assignedAndActive" /
    "assignedAndInactive" / "assignedAndOnHold" /
    "revoked" / "transferPending" / "registryLock" /
    "registrarLock" / "other" / "unknown" / "ext-value"
  ? ext-domain-status: text
  ? observable-id: IDtype
  Name: text
  ? DateDomainWasChecked: DATETIME
  ? RegistrationDate: DATETIME
  ? ExpirationDate: DATETIME
  ? RelatedDNS: [+ ExtensionType]
  ? NameServers: [+ NameServers]
  ? DomainContacts: DomainContacts
}
```

```
NameServers = {
  Server: text
  Address: [+ Address]
}
```

```
DomainContacts = {
  (SameDomainContact: text // Contact: [+ Contact])
}
```

```
Service = {
  ? ip-protocol: integer
  ? observable-id: IDtype
  ? ServiceName: ServiceName
  ? Port: integer
  ? Portlist: PortlistType
  ? ProtoCode: integer
  ? ProtoType: integer
  ? ProtoField: integer
  ? ApplicationHeaderField: [+ ExtensionType]
  ? EmailData: EmailData
  ? Application: SoftwareType
}
```

```
ServiceName = {
  ? IANAService: text
  ? URL: [+ URLtype]
  ? Description: [+ MLStringType]
}
```

```
EmailData = {
  ? observable-id: IDtype
  ? EmailTo: [+ text]
  ? EmailFrom: text
  ? EmailSubject: text
  ? EmailX-Mailer: text
  ? EmailHeaderField: [+ ExtensionType]
  ? EmailHeaders: text
  ? EmailBody: text
  ? EmailMessage: text
  ? HashData: [+ HashData]
  ? Signature: [+ SignatureType]
}

SignatureType = {
  ? id: IDtype
  SignedInfo: SignedInfoType
  SignatureValue: SignatureValueType
  ? KeyInfo: KeyInfoType
  ? Object: [+ ObjectType]
}

SignedInfoType = {
  ? id: IDtype
  CanonicalizationMethod: CanonicalizationMethodType
  SignatureMethod: SignatureMethodType
  Reference: [+ ReferenceType]
}

SignatureMethodType = {
  ? value: text
  Algorithm: URLtype
  ? HMACOutputLength: HMACOutputLengthType
}

HMACOutputLengthType = integer

ReferenceType = {
  ? id: IDtype
  ? URI: URLtype
  ? Type: URLtype
  ? Transforms: TransformsType
  DigestMethod: DigestMethodType
  DigestValue: DigestValueType
}

TransformsType = {
  Transform: [+ TransformType]
```

```
}

TransformType = {
  ? value: text
  Algorithm: URLtype
  ? XPath: [+ text]
}

DigestMethodType = {
  ? value: text
  Algorithm: URLtype
}

DigestValueType = BYTE

SignatureValueType = {
  value: BYTE
  ? id: IDtype
}

KeyInfoType = {
  ? value: text
  ? id: IDtype
  KeyProperties: [+ {KeyName: text} / {KeyValue: KeyValueTypes} /
                    {RetrievalMethod: RetrievalMethodType} /
                    {X509Data: X509DataType} / {PGPData: PGPDataType} /
                    {SPKIData: SPKIDDataType} / {MgmtData: text}]
}

KeyValueTypes = {
  ? value: text
  KeyValueProperties: {DSAKeyValue: DSAKeyValueTypes} /
                     {RSAKeyValue: RSAKeyValueTypes}
}

DSAKeyValueTypes = {
  ? P: CryptoBinary
  ? Q: CryptoBinary
  ? G: CryptoBinary
  Y: CryptoBinary
  ? J: CryptoBinary
  ? Seed: CryptoBinary
  ? PgenCounter: CryptoBinary
}

CryptoBinary = BYTE

RSAKeyValueTypes = {
```

```
    Modulus: CryptoBinary
    Exponent: CryptoBinary
  }

RetrievalMethodType = {
  URI: URLtype
  ? Type: URLtype
  ? Transforms: TransformsType
}

PGPDataType = {
  ? value: text
  PGPDataProperties: {PGPKeyID: BYTE} / {PGPKeyPacket: BYTE}
}

SPKIDDataType = {
  ? value: text
  SPKISexp: [+ BYTE]
}

ObjectType = {
  ? value: text
  ? id: IDtype
  ? MimeType: text
  ? Encoding: URLtype
}

RecordData = {
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  ? observable-id: IDtype
  ? DateTime: DATETIME
  ? Description: [+ MLStringType]
  ? Application: SoftwareType
  ? RecordPattern: [+ RecordPattern]
  ? RecordItem: [+ ExtensionType]
  ? URL: [+ URLtype]
  ? FileData: [+ FileData]
  ? WindowsRegistryKeysModified: [+ WindowsRegistryKeysModified]
  ? CertificateData: [+ CertificateData]
  ? AdditionalData: [+ ExtensionType]
}

RecordPattern = {
  value: text
  type: "regex" / "binary" / "xpath" / "ext-value" .default "regex"
  ? ext-type: text
}
```

```
? offset: integer
? offsetunit: "line" / "byte" / "ext-value" .default "line"
? ext-offsetunit: text
? instance: integer
}

WindowsRegistryKeysModified = {
  ? observable-id: IDtype
  Key: [+ Key]
}

Key = {
  ? registryaction: "add-key" / "add-value" / "delete-key" /
    "delete-value" / "modify-key" / "modify-value" /
    "ext-value"
  ? ext-registryaction: text
  ? observable-id: IDtype
  KeyName: text
  ? KeyValue: text
}

CertificateData = {
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  ? observable-id: IDtype
  Certificate: [+ Certificate]
}

Certificate = {
  ? observable-id: IDtype
  X509Data: X509DataType
  ? Description: [+ MLStringType]
}

X509DataType = {
  X509DataProperties: [+ {X509IssuerSerial: X509IssuerSerialType} /
    {X509SKI: BYTE} / {X509SubjectName: text} /
    {X509Certificate: BYTE} /
    {X509CRL: BYTE}]
}

X509IssuerSerialType = {
  X509IssuerName: text
  X509SerialNumber: integer
}

FileData = {
  ? restriction: restriction .default "private"
```

```
? ext-restriction: text
? observable-id: IDtype
File: [+ File]
}
```

```
File = {
  ? observable-id: IDtype
  ? FileName: text
  ? FileSize: integer
  ? FileType: text
  ? URL: [+ URLtype]
  ? HashData: HashData
  ? Signature: [+ SignatureType]
  ? AssociatedSoftware: SoftwareType
  ? FileProperties: [+ ExtensionType]
}
```

```
HashData = {
  scope: "file-contents" / "file-pe-section" / "file-pe-iat" /
        "file-pe-resource" / "file-pdf-object" / "email-hash" /
        "email-headers-hash" / "email-body-hash" / "ext-value"
  ? HashTargetID: text
  ? Hash: [+ Hash]
  ? FuzzyHash: [+ FuzzyHash]
}
```

```
Hash = {
  DigestMethod: DigestMethodType
  DigestValue: DigestValueType
  ? CanonicalizationMethod: CanonicalizationMethodType
  ? Application: SoftwareType
}
```

```
CanonicalizationMethodType = {
  ? value: text
  Algorithm: URLtype
}
```

```
FuzzyHash = {
  FuzzyHashValue: [+ ExtensionType]
  ? Application: SoftwareType
  ? AdditionalData: [+ ExtensionType]
}
```

```
Indicator = {
  ? restriction: restriction .default "private"
  ? ext-restriction: text
}
```



```
IndicatorID: IndicatorID
? AlternativeIndicatorID: [+ AlternativeIndicatorID]
? Description: [+ MLStringType]
? StartTime: DATETIME
? EndTime: DATETIME
? Confidence: Confidence
? Contact: [+ Contact]
(Observable: Observable // uid-ref: IDREFType //
  IndicatorExpression: IndicatorExpression //
  IndicatorReference: IndicatorReference)
? NodeRole: [+ NodeRole]
? AttackPhase: [+ AttackPhase]
? Reference: [+ Reference]
? AdditionalData: [+ ExtensionType]
}

IndicatorID = {
  id: IDtype
  name: text
  version: text
}

AlternativeIndicatorID = {
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  IndicatorReference: [+ IndicatorReference]
}

Observable = {
  ? restriction: restriction .default "private"
  ? ext-restriction: text
  ? (System: System // Address: Address // DomainData: DomainData //
    EmailData: EmailData // Service: Service //
    WindowsRegistryKeysModified: WindowsRegistryKeysModified //
    FileData: FileData // CertificateData: CertificateData //
    RegistryHandle: RegistryHandle // RecordData: RecordData //
    EventData: EventData // Incident: Incident // Expectation: Expectation //
    Reference: Reference // Assessment: Assessment //
    DetectionPattern: DetectionPattern // HistoryItem: HistoryItem //
    BulkObservable: BulkObservable // AdditionalData: [+ ExtensionType])
}

BulkObservable = {
  ? type: "asn" / "atm" / "e-mail" / "ipv4-addr" / "ipv4-net" /
    "ipv4-net-mask" / "ipv6-addr" / "ipv6-net" / "ipv6-net-mask" /
    "mac" / "site-uri" / "domain-name" / "domain-to-ipv4" /
    "domain-to-ipv6" / "domain-to-ipv4-timestamp" /
    "domain-to-ipv6-timestamp" / "ipv4-port" / "ipv6-port" /
```

```

        "windows-reg-key" / "file-hash" / "email-x-mailer" /
        "email-subject" / "http-user-agent" / "http-request-uri" /
        "mutex" / "file-path" / "user-name" / "ext-value"
    ? ext-type: text
    ? BulkObservableFormat: BulkObservableFormat
BulkObservableList: text
    ? AdditionalData: [+ ExtensionType]
}

BulkObservableFormat = {
    ? Hash: Hash
    ? AdditionalData: [+ ExtensionType]
}

IndicatorExpression = {
    ? operator: "not" / "and" / "or" / "xor" .default "and"
    ? ext-operator: text
    ? IndicatorExpression: [+ IndicatorExpression]
    ? Observable: [+ Observable]
    ? uid-ref: [+ IDREFTType]
    ? IndicatorReference: [+ IndicatorReference]
    ? Confidence: Confidence
    ? AdditionalData: [+ ExtensionType]
}

IndicatorReference = {
    ? uid-ref: IDREFTType
    ? euid-ref: text
    ? version: text
}

AttackPhase = {
    ? AttackPhaseID: [+ text]
    ? URL: [+ URLtype]
    ? Description: [+ MLStringType]
    ? AdditionalData: [+ ExtensionType]
}

```

Figure 7: Data Model in CDDL

## 6. Acknowledgements

We would like to thank Henk Birkholz, Carsten Bormann, Yasuaki Morita, and Takahiko Nagata for their insightful comments on CDDL.

## 7. IANA Considerations

This document registers a JSON schema.

## 8. Security Considerations

This memo does not provide any further security considerations than the one described in [RFC7970].

## 9. References

### 9.1. Normative References

- [cddl-spec] Henk Birkholz, Christoph Vigano, and Carsten Bormann, "Concise data definition language (CDDL): a notational convention to express CBOR and JSON data structures", 2018.
- [RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <<https://www.rfc-editor.org/info/rfc2119>>.
- [RFC7203] Takahashi, T., Landfield, K., and Y. Kadobayashi, "An Incident Object Description Exchange Format (IODEF) Extension for Structured Cybersecurity Information", RFC 7203, DOI 10.17487/RFC7203, April 2014, <<https://www.rfc-editor.org/info/rfc7203>>.
- [RFC7970] Danyliw, R., "The Incident Object Description Exchange Format Version 2", RFC 7970, DOI 10.17487/RFC7970, November 2016, <<https://www.rfc-editor.org/info/rfc7970>>.

### 9.2. Informative References

- [json-schema] Francis Galiegue, Kris Zyp, and Gary Court, "JSON Schema: core definitions and terminology", 2013.

## Appendix A. Data Types used in this document

The CDDL prelude used in this document is mapped to JSON as shown in the table below.

CDDL Prelude	Use of JSON	Instance	Validation
bytes	n/a	string	tool available
text	string	string	unnecessary
tdate	n/a	string	7.3.1 date-time
integer	n/a	number	integer
eb64legacy	n/a	string	tool available
uri	n/a	string	7.3.6 uri
float32	float32	number	unnecessary

Figure 8

## Appendix B. The IODEF Data Model (JSON Schema)

This section provides a JSON schema that defines the IODEF Data Model defined in this draft.

```
{ "$schema": "http://json-schema.org/draft-04/schema#",
  "definitions": {
    "action": { "enum": [ "nothing", "contact-source-site",
      "contact-target-site", "contact-sender", "investigate",
      "block-host", "block-network", "block-port", "rate-limit-host",
      "rate-limit-network", "rate-limit-port", "redirect-traffic",
      "honeypot", "upgrade-software", "rebuild-asset", "harden-asset",
      "remediate-other", "status-triage", "status-new-info",
      "watch-and-report", "training", "defined-coa", "other",
      "ext-value" ] },
    "duration": { "enum": [ "second", "minute", "hour", "day", "month",
      "quarter", "year", "ext-value" ] },
    "SpecID": {
      "enum": [ "urn:ietf:params:xml:ns:mile:mmdef:1.2", "private" ] },
    "lang": {
      "type": "string", "pattern": "^$|[a-zA-Z]{1,8}(-[a-zA-Z0-9]{1,8})*",
    "purpose": { "enum": [ "traceback", "mitigation", "reporting", "watch",
      "other", "ext-value" ] },
    "restriction": { "enum": [ "public", "partner", "need-to-know", "private",
      "default", "white", "green", "amber", "red", "ext-value" ] },
    "status": { "enum": [ "new", "in-progress", "forwarded", "resolved",
      "future", "ext-value" ] },
    "DATETIME": { "type": "string", "format": "date-time" },
    "BYTE": { "type": "string" },
    "PortlistType": {
      "type": "string", "pattern": "\\d+(\\-\\d+)?(,\\d+(\\-\\d+)?)*",
    "TimeZonetype": {
      "type": "string", "pattern": "Z|([\\+\\-])(0[0-9]|1[0-4]):[0-5][0-9]",
    "URLtype": {
```

```

    "type": "string",
    "pattern":
      "^(([/?:#]+):)?(//(([/?:#]*))?([/?:#]*(\\?([/?:#]*))?(#.*)?)?)",
    "IDType": {"type": "string", "pattern": "[a-zA-Z_][a-zA-Z0-9_.-]*"},
    "IDREFType": {"$ref": "#/definitions/IDType"},
    "CryptoBinary": {"$ref": "#/definitions/BYTE"},
    "MLStringType": {
      "oneOf": [{ "type": "string" },
        { "type": "object",
          "properties": {
            "value": {"type": "string"},
            "lang": {"$ref": "#/definitions/lang"},
            "translation-id": {"type": "string"}},
          "required": ["value"],
          "additionalProperties": false}}],
    "PositiveFloatType": {"type": "number", "minimum": 0},
    "PAddressType": {"$ref": "#/definitions/MLStringType"},
    "ExtensionType": {
      "type": "object",
      "properties": {
        "value": {"type": "string"},
        "name": {"type": "string"},
        "dtype": {"enum": ["boolean", "byte", "bytes", "character", "json",
          "date-time", "ntpstamp", "integer", "portlist", "real", "string",
          "file", "path", "frame", "packet", "ipv4-packet", "ipv6-packet",
          "url", "csv", "winreg", "xml", "ext-value"], "default": "string"},
        "ext-dtype": {"type": "string"},
        "meaning": {"type": "string"},
        "formatid": {"type": "string"},
        "restriction": {
          "$ref": "#/definitions/restriction", "default": "private"},
        "ext-restriction": {"type": "string"},
        "observable-id": {"$ref": "#/definitions/IDType"}},
      "required": ["value", "dtype"],
      "additionalProperties": false},
    "ExtensionTypeList": {
      "type": "array",
      "items": {"$ref": "#/definitions/ExtensionType"},
      "minItems": 1},
    "SoftwareType": {
      "type": "object",
      "properties": {
        "SoftwareReference": {"$ref": "#/definitions/SoftwareReference"},
        "URL": {
          "type": "array",
          "items": {"$ref": "#/definitions/URLtype"},
          "minItems": 1}},
      "Description": {

```

```

        "type": "array",
        "items": { "$ref": "#/definitions/MLStringType" },
        "minItems": 1 }},
    "required": [],
    "additionalProperties": false},
    "SoftwareReference": {
        "type": "object",
        "properties": {
            "value": { "type": "string" },
            "spec-name": { "enum": [ "custom", "cpe", "swid", "ext-value" ] },
            "ext-spec-name": { "type": "string" },
            "dtype": { "enum": [ "bytes", "integer", "real", "string", "xml",
                                "ext-value" ], "default": "string" },
            "ext-dtype": { "type": "string" } },
        "required": [ "spec-name" ],
        "additionalProperties": false},
    "StructuredInfo": {
        "type": "object",
        "properties": {
            "SpecID": { "$ref": "#/definitions/SpecID" },
            "ext-SpecID": { "type": "string" },
            "ContentID": { "type": "string" },
            "RawData": {
                "type": "array",
                "items": { "$ref": "#/definitions/BYTE" },
                "minItems": 1
            },
        },
        "Reference": {
            "type": "array",
            "items": { "$ref": "#/definitions/Reference" },
            "minItems": 1
        },
        "Platform": {
            "type": "array",
            "items": { "$ref": "#/definitions/Platform" },
            "minItems": 1
        },
        "Scoring": {
            "type": "array",
            "items": { "$ref": "#/definitions/Scoring" },
            "minItems": 1 }},
    "allof": [
        { "required": [ "SpecID" ] },
        { "anyOf": [
            { "oneOf": [
                { "required": [ "Reference" ] },
                { "required": [ "RawData" ] } ] },
            { "not": { "required": [ "Reference", "RawData" ] } } ] } ],

```

```
    "additionalProperties": false},
  "Platform": {
    "type": "object",
    "properties": {
      "SpecID": {"$ref": "#/definitions/SpecID"},
      "ext-SpecID": {"type": "string"},
      "ContentID": {"type": "string"},
      "RawData": {
        "type": "array",
        "items": {"$ref": "#/definitions/BYTE"},
        "minItems": 1
      },
    },
    "Reference": {
      "type": "array",
      "items": {"$ref": "#/definitions/Reference"},
      "minItems": 1}},
    "required": ["SpecID"],
    "additionalProperties": false},
  "Scoring": {
    "type": "object",
    "properties": {
      "SpecID": {"$ref": "#/definitions/SpecID"},
      "ext-SpecID": {"type": "string"},
      "ContentID": {"type": "string"},
      "RawData": {
        "type": "array",
        "items": {"$ref": "#/definitions/BYTE"},
        "minItems": 1
      },
    },
    "Reference": {
      "type": "array",
      "items": {"$ref": "#/definitions/Reference"},
      "minItems": 1}},
    "required": ["SpecID"],
    "additionalProperties": false},
  "Incident": {
    "title": "Incident",
    "description": "JSON schema for Incident class",
    "type": "object",
    "properties": {
      "purpose": {"$ref": "#/definitions/purpose"},
      "ext-purpose": {"type": "string"},
      "status": {"$ref": "#/definitions/status"},
      "ext-status": {"type": "string"},
      "lang": {"$ref": "#/definitions/lang"},
      "restriction": {"$ref": "#/definitions/restriction",
        "default": "private"},
      "ext-restriction": {"type": "string"},
    }
  }
}
```

```
"observable-id": {"$ref": "#/definitions/IDtype"},
"IncidentID": {"$ref": "#/definitions/IncidentID"},
"AlternativeID": {"$ref": "#/definitions/AlternativeID"},
"RelatedActivity": {
  "type": "array",
  "items": {"$ref": "#/definitions/RelatedActivity"},
  "minItems": 1},
"DetectTime": {"$ref": "#/definitions/DATETIME"},
"StartTime": {"$ref": "#/definitions/DATETIME"},
"EndTime": {"$ref": "#/definitions/DATETIME"},
"RecoveryTime": {"$ref": "#/definitions/DATETIME"},
"ReportTime": {"$ref": "#/definitions/DATETIME"},
"GenerationTime": {"$ref": "#/definitions/DATETIME"},
"Description": {
  "type": "array",
  "items": {"$ref": "#/definitions/MLStringType"},
  "minItems": 1},
"Discovery": {
  "type": "array",
  "items": {"$ref": "#/definitions/Discovery"},
  "minItems": 1},
"Assessment": {
  "type": "array",
  "items": {"$ref": "#/definitions/Assessment"},
  "minItems": 1},
"Method": {
  "type": "array",
  "items": {"$ref": "#/definitions/Method"},
  "minItems": 1},
"Contact": {
  "type": "array",
  "items": {"$ref": "#/definitions/Contact"},
  "minItems": 1},
"EventData": {
  "type": "array",
  "items": {"$ref": "#/definitions/EventData"},
  "minItems": 1},
"Indicator": {
  "type": "array",
  "items": {"$ref": "#/definitions/Indicator"},
  "minItems": 1},
"History": {"$ref": "#/definitions/History"},
"AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
"required": ["IncidentID", "GenerationTime", "Contact", "purpose"],
"additionalProperties": false},
"IncidentID": {
  "title": "IncidentID",
  "description": "JSON schema for IncidentID class",
```



```
"type": "object",
"properties": {
  "id": {"type": "string"},
  "name": {"type": "string"},
  "instance": {"type": "string"},
  "restriction": {"$ref": "#/definitions/restriction",
    "default": "private"},
  "ext-restriction": {"type": "string"}},
"required": ["id", "name"],
"additionalProperties": false},
"AlternativeID": {
  "title": "AlternativeID",
  "description": "JSON schema for AlternativeID class",
  "type": "object",
  "properties": {
    "IncidentID": {
      "type": "array",
      "items": {"$ref": "#/definitions/IncidentID"},
      "minItems": 1},
    "restriction": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"}},
  "required": ["IncidentID"],
  "additionalProperties": false},
"RelatedActivity": {
  "properties": {
    "restriction": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"},
    "IncidentID": {
      "type": "array",
      "items": {"$ref": "#/definitions/IncidentID"},
      "minItems": 1},
    "URL": {
      "type": "array",
      "items": {"$ref": "#/definitions/URLtype"},
      "minItems": 1},
    "ThreatActor": {
      "type": "array",
      "items": {"$ref": "#/definitions/ThreatActor"},
      "minItems": 1},
    "Campaign": {
      "type": "array",
      "items": {"$ref": "#/definitions/Campaign"},
      "minItems": 1},
    "IndicatorID": {
      "type": "array",
      "items": {"$ref": "#/definitions/IndicatorID"},
```

```
    "minItems": 1},
    "Confidence": {"$ref": "#/definitions/Confidence"},
    "Description": {
      "type": "array",
      "items": {"type": "string"},
      "minItems": 1},
    "AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
    "additionalProperties": false},
  "ThreatActor": {
    "properties": {
      "restriction": {"$ref": "#/definitions/restriction",
                     "default": "private"},
      "ext-restriction": {"type": "string"},
      "ThreatActorID": {
        "type": "array",
        "items": {"type": "string"},
        "minItems": 1},
      "Description": {
        "type": "array",
        "items": {"$ref": "#/definitions/MLStringType"},
        "minItems": 1},
      "URL": {
        "type": "array",
        "items": {"$ref": "#/definitions/URLtype"},
        "minItems": 1},
      "AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
    "additionalProperties": false},
  "Campaign": {
    "properties": {
      "restriction": {"$ref": "#/definitions/restriction",
                     "default": "private"},
      "ext-restriction": {"type": "string"},
      "CampaignID": {
        "type": "array",
        "items": {"type": "string"},
        "minItems": 1},
      "URL": {
        "type": "array",
        "items": {"$ref": "#/definitions/URLtype"},
        "minItems": 1},
      "Description": {
        "type": "array",
        "items": {"$ref": "#/definitions/MLStringType"},
        "minItems": 1},
      "AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
    "AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
  "Contact": {
    "type": "object",
    "properties": {
```

```
"role": {
  "enum": ["creator", "reporter", "admin", "tech", "provider", "user",
    "billing", "legal", "irt", "abuse", "cc", "cc-irt", "leo",
    "vendor", "vendor-support", "victim", "victim-notified",
    "ext-value"]},
"ext-role": {"type": "string"},
"type": {"enum": ["person", "organization", "ext-value"]},
"ext-type": {"type": "string"},
"restriction": {"$ref": "#/definitions/restriction",
  "default": "private"},
"ext-restriction": {"type": "string"},
"ContactName": {
  "type": "array",
  "items": {"$ref": "#/definitions/MLStringType"},
  "minItems": 1},
"ContactTitle": {
  "type": "array",
  "items": {"$ref": "#/definitions/MLStringType"},
  "minItems": 1},
"Description": {
  "type": "array",
  "items": {"$ref": "#/definitions/MLStringType"},
  "minItems": 1},
"RegistryHandle": {
  "type": "array",
  "items": {"$ref": "#/definitions/RegistryHandle"},
  "minItems": 1},
"PostalAddress": {
  "type": "array",
  "items": {"$ref": "#/definitions/PostalAddress"},
  "minItems": 1},
"Email": {
  "type": "array",
  "items": {"$ref": "#/definitions/Email"},
  "minItems": 1},
"Telephone": {
  "type": "array",
  "items": {"$ref": "#/definitions/Telephone"},
  "minItems": 1},
"Timezone": {"$ref": "#/definitions/TimeZonetype"},
"Contact": {
  "type": "array",
  "items": {"$ref": "#/definitions/Contact"},
  "minItems": 1},
  "AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
"required": ["role", "type"],
"additionalProperties": false},
"RegistryHandle": {
```

```
"type": "object",
"properties": {
  "handle": {"type": "string"},
  "registry": {
    "enum": ["internic","apnic","arin","lacnic","ripe","afrinic",
            "local","ext-value"]},
  "ext-registry": {"type": "string"}},
"required": ["handle","registry"],
"additionalProperties": false},
"PostalAddress": {
  "type": "object",
  "properties": {
    "type": {
      "enum": ["street","mailing","ext-value"]},
    "ext-type": {"type": "string"},
    "PAddress": {"$ref": "#/definitions/PAddressType"},
    "Description": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1}},
    "required": ["PAddress"],
    "additionalProperties": false},
"Email": {
  "type": "object",
  "properties": {
    "type": {
      "enum": ["direct","hotline","ext-value"]},
    "ext-type": {"type": "string"},
    "EmailTo": {"type": "string"},
    "Description": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1}},
    "required": ["EmailTo"],
    "additionalProperties": false},
"Telephone": {
  "type": "object",
  "properties": {
    "type": {
      "enum": ["wired","mobile","fax","hotline","ext-value"]},
    "ext-type": {"type": "string"},
    "TelephoneNumber": {"type": "string"},
    "Description": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1}},
    "required": ["TelephoneNumber"],
    "additionalProperties": false},
```

```
"Discovery": {
  "type": "object",
  "properties": {
    "source": {
      "enum": [ "nids", "hips", "siem", "av", "third-party-monitoring",
        "incident", "os-log", "application-log", "device-log",
        "network-flow", "passive-dns", "investigation", "audit",
        "internal-notification", "external-notification", "leo",
        "partner", "actor", "unknown", "ext-value" ],
      "ext-source": { "type": "string" },
      "restriction": { "$ref": "#/definitions/restriction",
        "default": "private" },
      "ext-restriction": { "type": "string" },
      "Description": {
        "type": "array",
        "items": { "$ref": "#/definitions/MLStringType" },
        "minItems": 1 },
      "Contact": {
        "type": "array",
        "items": { "$ref": "#/definitions/Contact" },
        "minItems": 1 },
      "DetectionPattern": {
        "type": "array",
        "items": { "$ref": "#/definitions/DetectionPattern" },
        "minItems": 1 } },
    "required": [],
    "additionalProperties": false },
  "DetectionPattern": {
    "type": "object",
    "properties": {
      "restriction": { "$ref": "#/definitions/restriction",
        "default": "private" },
      "ext-restriction": { "type": "string" },
      "observable-id": { "$ref": "#/definitions/IDtype" },
      "Application": { "$ref": "#/definitions/SoftwareType" },
      "Description": {
        "type": "array",
        "items": { "$ref": "#/definitions/MLStringType" },
        "minItems": 1 },
      "DetectionConfiguration": {
        "type": "array",
        "items": { "type": "string" },
        "minItems": 1 } },
    "required": [ "Application" ],
    "additionalProperties": false },
  "Method": {
    "type": "object",
    "properties": {
```

```
"restriction": { "$ref": "#/definitions/restriction",
                  "default": "private" },
"ext-restriction": { "type": "string" },
"Reference": {
  "type": "array",
  "items": { "$ref": "#/definitions/Reference" },
  "minItems": 1 },
"Description": {
  "type": "array",
  "items": { "$ref": "#/definitions/MLStringType" },
  "minItems": 1 },
"AttackPattern": {
  "type": "array",
  "items": { "$ref": "#/definitions/StructuredInfo" },
  "minItems": 1 },
"Vulnerability": {
  "type": "array",
  "items": { "$ref": "#/definitions/StructuredInfo" },
  "minItems": 1 },
"Weakness": {
  "type": "array",
  "items": { "$ref": "#/definitions/StructuredInfo" },
  "minItems": 1 },
"AdditionalData": { "$ref": "#/definitions/ExtensionTypeList" } },
"required": [],
"additionalProperties": false },
"Reference": {
  "type": "object",
  "properties": {
    "observable-id": { "$ref": "#/definitions/IDtype" },
    "ReferenceName": { "$ref": "#/definitions/ReferenceName" },
    "URL": {
      "type": "array",
      "items": { "$ref": "#/definitions/URLtype" },
      "minItems": 1 },
    "Description": {
      "type": "array",
      "items": { "$ref": "#/definitions/MLStringType" },
      "minItems": 1 } },
  "required": [],
  "additionalProperties": false },
"ReferenceName": {
  "type": "object",
  "properties": {
    "specIndex": { "type": "number" },
    "ID": { "$ref": "#/definitions/IDtype" } },
  "required": [ "specIndex", "ID" ],
  "additionalProperties": false },
```

```
"Assessment": {
  "type": "object",
  "properties": {
    "occurrence": {"enum":["actual","potential"]},
    "restriction": {"$ref": "#/definitions/restriction",
                  "default": "private"},
    "ext-restriction": {"type": "string"},
    "observable-id": {"$ref": "#/definitions/IDtype"},
    "IncidentCategory": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1},
    "Impact": {
      "type": "array",
      "items": {
        "properties": {
          "SystemImpact":{"$ref":"#/definitions/SystemImpact"},
          "BusinessImpact":{"$ref":"#/definitions/BusinessImpact"},
          "TimeImpact":{"$ref":"#/definitions/TimeImpact"},
          "MonetaryImpact":{"$ref":"#/definitions/MonetaryImpact"},
          "IntendedImpact":{"$ref":"#/definitions/BusinessImpact"}},
        "additionalProperties":false},
      "minItems" : 1
    },
    "Counter": {
      "type": "array",
      "items": {"$ref": "#/definitions/Counter"},
      "minItems": 1},
    "MitigatingFactor": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1},
    "Cause": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1},
    "Confidence": {"$ref": "#/definitions/Confidence"},
    "AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
  "required": ["Impact"],
  "additionalProperties": false},
"SystemImpact": {
  "type": "object",
  "properties": {
    "severity": {"enum":["low","medium","high"]},
    "completion": {"enum":["failed","succeeded"]},
    "type": {
      "enum":["takeover-account","takeover-service",
            "takeover-system","cps-manipulation","cps-damage",
```

```

    "availability-data", "availability-account",
    "availability-service", "availability-system",
    "damaged-system", "damaged-data", "breach-proprietary",
    "breach-privacy", "breach-credential",
    "breach-configuration", "integrity-data",
    "integrity-configuration", "integrity-hardware",
    "traffic-redirection", "monitoring-traffic",
    "monitoring-host", "policy", "unknown", "ext-value"]},
  "ext-type": {"type": "string"},
  "Description": {
    "type": "array",
    "items": {"$ref": "#/definitions/MLStringType"},
    "minItems": 1}},
  "required": ["type"],
  "additionalProperties": false},
"BusinessImpact": {
  "type": "object",
  "properties": {
    "severity": {"enum": ["none", "low", "medium", "high", "unknown",
      "ext-value"], "default": "unknown"},
    "ext-severity": {"type": "string"},
    "type": {"enum": ["breach-proprietary", "breach-privacy",
      "breach-credential", "loss-of-integrity", "loss-of-service",
      "theft-financial", "theft-service", "degraded-reputation",
      "asset-damage", "asset-manipulation", "legal", "extortion",
      "unknown", "ext-value"]},
    "ext-type": {"type": "string"},
    "Description": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1}},
    "required": ["type"],
    "additionalProperties": false},
"TimeImpact": {
  "type": "object",
  "properties": {
    "value": {"$ref": "#/definitions/PositiveFloatType"},
    "severity": {"enum": ["low", "medium", "high"]},
    "metric": {"enum": ["labor", "elapsed", "downtime", "ext-value"]},
    "ext-metric": {"type": "string"},
    "duration": {"$ref": "#/definitions/duration", "default": "hour"},
    "ext-duration": {"type": "string"}},
    "required": ["value", "metric"],
    "additionalProperties": false},
"MonetaryImpact": {
  "type": "object",
  "properties": {
    "value": {"$ref": "#/definitions/PositiveFloatType"},

```



```
    "severity": {"enum": ["low", "medium", "high"]},
    "currency": {"type": "string"}},
  "required": ["value"],
  "additionalProperties": false},
"Confidence": {
  "type": "object",
  "properties": {
    "value": {"type": "number"},
    "rating": {"enum": ["low", "medium", "high", "numeric", "unknown",
      "ext-value"]},
    "ext-rating": {"type": "string"}},
  "required": ["value", "rating"],
  "additionalProperties": false},
"History": {
  "type": "object",
  "properties": {
    "restriction": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"},
    "HistoryItem": {
      "type": "array",
      "items": {"$ref": "#/definitions/HistoryItem"},
      "minItems": 1}},
  "required": ["HistoryItem"],
  "additionalProperties": false},
"HistoryItem": {
  "type": "object",
  "properties": {
    "action": {"$ref": "#/definitions/action", "default": "other"},
    "ext-action": {"type": "string"},
    "restriction": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"},
    "observable-id": {"$ref": "#/definitions/IDtype"},
    "DateTime": {"$ref": "#/definitions/DATETIME"},
    "IncidentID": {"$ref": "#/definitions/IncidentID"},
    "Contact": {"$ref": "#/definitions/Contact"},
    "Description": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1},
    "DefinedCOA": {
      "type": "array",
      "items": {"type": "string"},
      "minItems": 1},
    "AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
  "required": ["DateTime", "action"],
  "additionalProperties": false},
```

```
"EventData": {
  "type": "object",
  "properties": {
    "restriction": {"$ref": "#/definitions/restriction",
                    "default": "private"},
    "ext-restriction": {"type": "string"},
    "observable-id": {"$ref": "#/definitions/IDtype"},
    "Description": {"type": "array",
                    "items": {"$ref": "#/definitions/MLStringType"}},
    "DetectTime": {"$ref": "#/definitions/DATETIME"},
    "StartTime": {"$ref": "#/definitions/DATETIME"},
    "EndTime": {"$ref": "#/definitions/DATETIME"},
    "RecoveryTime": {"$ref": "#/definitions/DATETIME"},
    "ReportTime": {"$ref": "#/definitions/DATETIME"},
    "Contact": {
      "type": "array",
      "items": {"$ref": "#/definitions/Contact"},
      "minItems": 1},
    "Discovery": {
      "type": "array",
      "items": {"$ref": "#/definitions/Discovery"},
      "minItems": 1},
    "Assessment": {"$ref": "#/definitions/Assessment"},
    "Method": {
      "type": "array",
      "items": {"$ref": "#/definitions/Method"},
      "minItems": 1},
    "System": {
      "type": "array",
      "items": {"$ref": "#/definitions/System"},
      "minItems": 1},
    "Expectation": {
      "type": "array",
      "items": {"$ref": "#/definitions/Expectation"},
      "minItems": 1},
    "RecordData": {
      "type": "array",
      "items": {"$ref": "#/definitions/RecordData"},
      "minItems": 1},
    "EventData": {
      "type": "array",
      "items": {"$ref": "#/definitions/EventData"},
      "minItems": 1},
    "AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
  "required": [],
  "additionalProperties": false},
"Expectation": {
  "type": "object",
```

```
"properties": {
  "action": {"$ref": "#/definitions/action", "default": "other"},
  "ext-action": {"type": "string"},
  "severity": {"enum": ["low", "medium", "high"]},
  "restriction": {"$ref": "#/definitions/restriction",
    "default": "default"},
  "ext-restriction": {"type": "string"},
  "observable-id": {"$ref": "#/definitions/IDtype"},
  "Description": {
    "type": "array",
    "items": {"$ref": "#/definitions/MLStringType"},
    "minItems": 1},
  "DefinedCOA": {
    "type": "array",
    "items": {"type": "string"},
    "minItems": 1},
  "StartTime": {"$ref": "#/definitions/DATETIME"},
  "EndTime": {"$ref": "#/definitions/DATETIME"},
  "Contact": {"$ref": "#/definitions/Contact"}}},
"required": [],
"additionalProperties": false},
"System": {
  "type": "object",
  "properties": {
    "category": {
      "enum": ["source", "target", "intermediate", "sensor",
        "infrastructure", "ext-value"]},
    "ext-category": {"type": "string"},
    "interface": {"type": "string"},
    "spoofed": {"enum": ["unknown", "yes", "no"], "default": "unknown"},
    "virtual": {"enum": ["yes", "no", "unknown"], "default": "unknown"},
    "ownership": {
      "enum": ["organization", "personal", "partner", "customer",
        "no-relationship", "unknown", "ext-value"]},
    "ext-ownership": {"type": "string"},
    "restriction": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"},
    "observable-id": {"$ref": "#/definitions/IDtype"},
    "Node": {"$ref": "#/definitions/Node"},
    "NodeRole": {
      "type": "array",
      "items": {"$ref": "#/definitions/NodeRole"},
      "minItems": 1},
    "Service": {
      "type": "array",
      "items": {"$ref": "#/definitions/Service"},
      "minItems": 1},
```

```
"OperatingSystem": {
  "type": "array",
  "items": {"$ref": "#/definitions/SoftwareType"},
  "minItems": 1},
"Counter": {
  "type": "array",
  "items": {"$ref": "#/definitions/Counter"},
  "minItems": 1},
"AssetID": {
  "type": "array",
  "items": {"type": "string"},
  "minItems": 1},
"Description": {
  "type": "array",
  "items": {"$ref": "#/definitions/MLStringType"},
  "minItems": 1},
"AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
"required": ["Node"],
"additionalProperties": false},
"Node": {
  "type": "object",
  "properties": {
    "DomainData": {
      "type": "array",
      "items": {"$ref": "#/definitions/DomainData"},
      "minItems": 1},
    "Address": {
      "type": "array",
      "items": {"$ref": "#/definitions/Address"},
      "minItems": 1},
    "PostalAddress": {"$ref": "#/definitions/PostalAddress"},
    "Location": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1},
    "Counter": {
      "type": "array",
      "items": {"$ref": "#/definitions/Counter"},
      "minItems": 1}},
  "anyOf": [
    {"required": ["DomainData"]},
    {"required": ["Address"]}
  ],
  "additionalProperties": false},
"Address": {
  "type": "object",
  "properties": {
    "value": {"type": "string"},
```

```

"category": {
  "enum": ["asn", "atm", "e-mail", "ipv4-addr", "ipv4-net",
    "ipv4-net-masked", "ipv4-net-mask", "ipv6-addr", "ipv6-net",
    "ipv6-net-masked", "mac", "site-uri", "ext-value"],
  "default": "ipv6-addr"},
"ext-category": {"type": "string"},
"vlan-name": {"type": "string"},
"vlan-num": {"type": "number"},
"observable-id": {"$ref": "#/definitions/IDtype"}},
"required": ["value", "category"],
"additionalProperties": false},
"NodeRole": {
  "type": "object",
  "properties": {
    "category": {
      "enum": ["client", "client-enterprise", "client-partner",
        "client-remote", "client-kiosk", "client-mobile",
        "server-internal", "server-public", "www", "mail", "webmail",
        "messaging", "streaming", "voice", "file", "ftp", "p2p", "name",
        "directory", "credential", "print", "application", "database",
        "backup", "dhcp", "assessment", "source-control",
        "config-management", "monitoring", "infra", "infra-firewall",
        "infra-router", "infra-switch", "camera", "proxy",
        "remote-access", "log", "virtualization", "pos", "scada",
        "scada-supervisory", "sinkhole", "honeypot", "anonymization",
        "c2-server", "malware-distribution", "drop-server",
        "hop-point", "reflector", "phishing-site",
        "spear-phishing-site", "recruiting-site", "fraudulent-site",
        "ext-value"]},
      "ext-category": {"type": "string"},
      "Description": {
        "type": "array",
        "items": {"$ref": "#/definitions/MLStringType"},
        "minItems": 1}},
      "required": ["category"],
      "additionalProperties": false},
"Counter": {
  "type": "object",
  "properties": {
    "value": {"type": "number"},
    "type": {"enum": ["count", "peak", "average", "ext-value"]},
    "ext-type": {"type": "string"},
    "unit": {"enum": ["byte", "mbit", "packet", "flow", "session", "alert",
      "message", "event", "host", "site", "organization", "ext-value"]},
    "ext-unit": {"type": "string"},
    "meaning": {"type": "string"},
    "duration": {"$ref": "#/definitions/duration", "default": "hour"},
    "ext-duration": {"type": "string"}},

```

```
"required": ["value", "type", "unit"],
"additionalProperties": false},
"DomainData": {
  "type": "object",
  "properties": {
    "system-status": {
      "enum": ["spoofed", "fraudulent", "innocent-hacked",
        "innocent-hijacked", "unknown", "ext-value"]},
    "ext-system-status": {"type": "string"},
    "domain-status": {
      "enum": [ "reservedDelegation", "assignedAndActive",
        "assignedAndInactive", "assignedAndOnHold", "revoked",
        "transferPending", "registryLock", "registrarLock",
        "other", "unknown", "ext-value"]},
    "ext-domain-status": {"type": "string"},
    "observable-id": {"$ref": "#/definitions/IDtype"},
    "Name": {"type": "string"},
    "DateDomainWasChecked": {"$ref": "#/definitions/DATETIME"},
    "RegistrationDate": {"$ref": "#/definitions/DATETIME"},
    "ExpirationDate": {"$ref": "#/definitions/DATETIME"},
    "RelatedDNS": {
      "type": "array",
      "items": {"$ref": "#/definitions/ExtensionType"},
      "minItems": 1},
    "NameServers": {
      "type": "array",
      "items": {"$ref": "#/definitions/NameServers"},
      "minItems": 1},
    "DomainContacts": {"$ref": "#/definitions/DomainContacts"}},
  "required": ["Name", "system-status", "domain-status"],
  "additionalProperties": false},
"NameServers": {
  "type": "object",
  "properties": {
    "Server": {"type": "string"},
    "Address": {
      "type": "array",
      "items": {"$ref": "#/definitions/Address"},
      "minItems": 1}},
  "required": ["Server", "Address"],
  "additionalProperties": false},
"DomainContacts": {
  "type": "object",
  "properties": {
    "SameDomainContact": {"type": "string"},
    "Contact": {
      "type": "array",
      "items": {"$ref": "#/definitions/Contact"}},
```

```
    "minItems": 1}},
  "oneOf": [
    {"required": ["SameDomainContact"]},
    {"required": ["Contact"]}],
  "additionalProperties": false},
"Service": {
  "type": "object",
  "properties": {
    "ip-protocol": {"type": "number"},
    "observable-id": {"$ref": "#/definitions/IDtype"},
    "ServiceName": {"$ref": "#/definitions/ServiceName"},
    "Port": {"type": "number"},
    "Portlist": {"$ref": "#/definitions/PortlistType"},
    "ProtoCode": {"type": "number"},
    "ProtoType": {"type": "number"},
    "ProtoField": {"type": "number"},
    "ApplicationHeaderField": {
      "$ref": "#/definitions/ExtensionTypeList"},
    "EmailData": {"$ref": "#/definitions/EmailData"},
    "Application": {"$ref": "#/definitions/SoftwareType"}},
  "required": [],
  "additionalProperties": false},
"ServiceName": {
  "type": "object",
  "properties": {
    "IANAService": {"type": "string"},
    "URL": {"type": "array", "items": {"$ref": "#/definitions/URLtype"}},
    "Description": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1}},
  "required": [],
  "additionalProperties": false},
"EmailData": {
  "type": "object",
  "properties": {
    "observable-id": {"$ref": "#/definitions/IDtype"},
    "EmailTo": {
      "type": "array",
      "items": {"type": "string"},
      "minItems": 1},
    "EmailFrom": {"type": "string"},
    "EmailSubject": {"type": "string"},
    "EmailX-Mailer": {"type": "string"},
    "EmailHeaderField": {
      "type": "array",
      "items": {"$ref": "#/definitions/ExtensionType"},
      "minItems": 1},
```

```
"EmailHeaders": {"type": "string"},
"EmailBody": {"type": "string"},
"EmailMessage": {"type": "string"},
"HashData": {
  "type": "array",
  "items": {"$ref": "#/definitions/HashData"},
  "minItems": 1},
"Signature": {
  "type": "array",
  "items": {"$ref": "#/definitions/SignatureType"},
  "minItems": 1}},
"required": [],
"additionalProperties": false},
"SignatureType": {
  "type": "object",
  "properties": {
    "id": {"$ref": "#/definitions/IDtype"},
    "SignedInfo": {"$ref": "#/definitions/SignedInfoType"},
    "SignatureValue": {"$ref": "#/definitions/SignatureValueType"},
    "KeyInfo": {"$ref": "#/definitions/KeyInfoType"},
    "Object": {
      "type": "array",
      "items": {"$ref": "#/definitions/ObjectType"},
      "minItems": 1}},
    "required": ["SignedInfo", "SignatureValue"],
    "additionalProperties": false
  },
  "SignatureValueType": {
    "type": "object",
    "properties": {
      "value": {"$ref": "#/definitions/BYTE"},
      "id": {"$ref": "#/definitions/IDtype"}
    },
    "required": ["value"],
    "additionalProperties": false
  },
  "SignedInfoType": {
    "type": "object",
    "properties": {
      "id": {"$ref": "#/definitions/IDtype"},
      "CanonicalizationMethod": {
        "$ref": "#/definitions/CanonicalizationMethodType"},
      "SignatureMethod": {"$ref": "#/definitions/SignatureMethodType"},
      "Reference": {
        "type": "array",
        "items": {"$ref": "#/definitions/ReferenceType"},
        "minItems": 1}
    },
  },
```



```
    "required": ["CanonicalizationMethod", "SignatureMethod",
      "Reference"],
    "additionalProperties": false
  },
  "SignatureMethodType": {
    "type": "object",
    "properties": {
      "value": {"type": "string"},
      "Algorithm": {"$ref": "#/definitions/URLtype"},
      "HMACOutputLength": {"$ref": "#/definitions/HMACOutputLengthType"}
    },
    "required": ["Algorithm"],
    "additionalProperties": false
  },
  "HMACOutputLengthType": {"type": "number"},
  "ReferenceType": {
    "type": "object",
    "properties": {
      "id": {"$ref": "#/definitions/IDtype"},
      "URI": {"$ref": "#/definitions/URLtype"},
      "Type": {"$ref": "#/definitions/URLtype"},
      "Transforms": {"$ref": "#/definitions/TransformsType"},
      "DigestMethod": {"$ref": "#/definitions/DigestMethodType"},
      "DigestValue": {"$ref": "#/definitions/DigestValueType"}
    },
    "required": ["DigestMethod", "DigestValue"],
    "additionalProperties": false
  },
  "TransformsType": {
    "type": "object",
    "properties": {
      "Transform": {
        "type": "array",
        "items": {"$ref": "#/definitions/TransformType"},
        "minItems": 1
      }
    },
    "required": ["Transform"],
    "additionalProperties": false
  },
  "TransformType": {
    "type": "object",
    "properties": {
      "value": {"type": "string"},
      "Algorithm": {"$ref": "#/definitions/URLtype"},
      "XPath": {
        "type": "array",
        "items": {"type": "string"},
        "minItems": 1
      }
    }
  }
```

```

    },
    "required": ["Algorithm"],
    "additionalProperties": false
  },
  "DigestMethodType": {
    "type": "object",
    "properties": {
      "value": {"type": "string"},
      "Algorithm": {"$ref": "#/definitions/URLtype"}
    },
    "required": ["Algorithm"],
    "additionalProperties": false
  },
  "DigestValueType": {"$ref": "#/definitions/BYTE"},
  "KeyInfoType": {
    "type": "object",
    "properties": {
      "value": {"type": "string"},
      "id": {"$ref": "#/definitions/IDtype"},
      "KeyProperties": {
        "type": "array",
        "items": {
          "type": "object",
          "properties": {
            "KeyName": {"type": "string"},
            "KeyValue": {"$ref": "#/definitions/KeyValue"},
            "RetrievalMethod": {
              {"$ref": "#/definitions/RetrievalMethodType"},
            },
            "X509Data": {"$ref": "#/definitions/X509DataType"},
            "PGPData": {"$ref": "#/definitions/PGPDataType"},
            "SPKIData": {"$ref": "#/definitions/SPKIDDataType"},
            "MgmtData": {"type": "string"}
          },
          "additionalProperties": false,
          "minItems": 1
        }
      },
      "required": ["KeyProperties"],
      "additionalProperties": false
    },
    "required": ["KeyProperties"],
    "additionalProperties": false
  },
  "KeyValue": {
    "type": "object",
    "properties": {
      "value": {"type": "string"},
      "KeyValueProperties": {
        "items": {
          "type": "object",
          "properties": {
            "DSAKeyValue": {"$ref": "#/definitions/DSAKeyValue"},
            "RSAKeyValue": {"$ref": "#/definitions/RSAKeyValue"}
          },
          "additionalProperties": false
        }
      }
    }
  }

```

```
    },
    "required": ["KeyValueProperties"],
    "additionalProperties": false
  },
  "DSASignKeyValueType": {
    "type": "object",
    "properties": {
      "P": {"$ref": "#/definitions/CryptoBinary"},
      "Q": {"$ref": "#/definitions/CryptoBinary"},
      "G": {"$ref": "#/definitions/CryptoBinary"},
      "Y": {"$ref": "#/definitions/CryptoBinary"},
      "J": {"$ref": "#/definitions/CryptoBinary"},
      "Seed": {"$ref": "#/definitions/CryptoBinary"},
      "PgenCounter": {"$ref": "#/definitions/CryptoBinary"}
    },
    "required": ["Y"],
    "additionalProperties": false
  },
  "RSAKeyValueType": {
    "type": "object",
    "properties": {
      "Modulus": {"$ref": "#/definitions/CryptoBinary"},
      "Exponent": {"$ref": "#/definitions/CryptoBinary"}
    },
    "required": ["Modulus", "Exponent"],
    "additionalProperties": false
  },
  "RetrievalMethodType": {
    "type": "object",
    "properties": {
      "URI": {"$ref": "#/definitions/URLtype"},
      "Type": {"$ref": "#/definitions/URLtype"},
      "Transforms": {"$ref": "#/definitions/TransformsType"}
    },
    "required": ["URI"],
    "additionalProperties": false
  },
  "PGPDataType": {
    "type": "object",
    "properties": {
      "value": {"type": "string"},
      "PGPDataProperties": {
        "items": {
          "type": "object",
          "properties": {
            "PGPKeyID": {"$ref": "#/definitions/BYTE"},
            "PGPKeyPacket": {"$ref": "#/definitions/BYTE"}
          },
          "additionalProperties": false
        }
      }
    }
  }
}
```

```
    "required": ["PGPDataProperties"],
    "additionalProperties": false
  },
  "SPKIDataType": {
    "type": "object",
    "properties": {
      "value": {"type": "string"},
      "SPKISexp": {
        "type": "array",
        "items": {"$ref": "#/definitions/BYTE"},
        "minItems": 1}
    },
    "required": ["SPKISexp"],
    "additionalProperties": false
  },
  "ObjectType": {
    "type": "object",
    "properties": {
      "value": {"type": "string"},
      "id": {"$ref": "#/definitions/IDtype"},
      "MimeType": {"type": "string"},
      "Encoding": {"$ref": "#/definitions/URLtype"}
    },
    "additionalProperties": false
  },
  "RecordData": {
    "type": "object",
    "properties": {
      "restriction": {"$ref": "#/definitions/restriction",
                     "default": "private"},
      "ext-restriction": {"type": "string"},
      "observable-id": {"$ref": "#/definitions/IDtype"},
      "DateTime": {"$ref": "#/definitions/DATETIME"},
      "Description": {
        "type": "array",
        "items": {"$ref": "#/definitions/MLStringType"},
        "minItems": 1},
      "Application": {"$ref": "#/definitions/SoftwareType"},
      "RecordPattern": {
        "type": "array",
        "items": {"$ref": "#/definitions/RecordPattern"},
        "minItems": 1},
      "RecordItem": {
        "type": "array",
        "items": {"$ref": "#/definitions/ExtensionType"},
        "minItems": 1},
      "URL": {
        "type": "array",
```

```
    "items": { "$ref": "#/definitions/URLtype" },
    "minItems": 1 },
  "FileData": {
    "type": "array",
    "items": { "$ref": "#/definitions/FileData" },
    "minItems": 1 },
  "WindowsRegistryKeysModified": {
    "type": "array",
    "items": { "$ref": "#/definitions/WindowsRegistryKeysModified" },
    "minItems": 1 },
  "CertificateData": {
    "type": "array",
    "items": { "$ref": "#/definitions/CertificateData" },
    "minItems": 1 },
  "AdditionalData": { "$ref": "#/definitions/ExtensionTypeList" },
  "required": [],
  "additionalProperties": false },
"RecordPattern": {
  "type": "object",
  "properties": {
    "value": { "type": "string" },
    "type": { "enum": [ "regex", "binary", "xpath", "ext-value" ],
              "default": "regex" },
    "ext-type": { "type": "string" },
    "offset": { "type": "number" },
    "offsetunit": { "enum": [ "line", "byte", "ext-value" ],
                   "default": "line" },
    "ext-offsetunit": { "type": "string" },
    "instance": { "type": "number" } },
  "required": [ "value", "type" ],
  "additionalProperties": false },
"WindowsRegistryKeysModified": {
  "type": "object",
  "properties": {
    "observable-id": { "$ref": "#/definitions/IDtype" },
    "Key": {
      "type": "array",
      "items": { "$ref": "#/definitions/Key" },
      "minItems": 1 } },
  "required": [ "Key" ],
  "additionalProperties": false },
"Key": {
  "type": "object",
  "properties": {
    "registryaction": { "enum": [ "add-key", "add-value", "delete-key",
                                "delete-value", "modify-key", "modify-value",
                                "ext-value" ] },
    "ext-registryaction": { "type": "string" },
```

```
    "observable-id": {"$ref": "#/definitions/IDtype"},
    "KeyName": {"type": "string"},
    "KeyValue": {"type": "string"}},
  "required": ["KeyName"],
  "additionalProperties": false},
"CertificateData": {
  "type": "object",
  "properties": {
    "restriction": {"$ref": "#/definitions/restriction",
                    "default": "private"},
    "ext-restriction": {"type": "string"},
    "observable-id": {"$ref": "#/definitions/IDtype"},
    "Certificate": {
      "type": "array",
      "items": {"$ref": "#/definitions/Certificate"},
      "minItems": 1}},
    "required": ["Certificate"],
    "additionalProperties": false},
"Certificate": {
  "type": "object",
  "properties": {
    "observable-id": {"$ref": "#/definitions/IDtype"},
    "X509Data": {"$ref": "#/definitions/X509DataType"},
    "Description": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1}},
    "required": ["X509Data"],
    "additionalProperties": false},
"X509DataType": {
  "type": "object",
  "properties": {
    "X509DataProperties": {
      "type": "array",
      "items": {
        "type": "object",
        "properties": {
          "X509IssuerSerial": {
            "$ref": "#/definitions/X509IssuerSerialType"},
          "X509SKI": {"$ref": "#/definitions/BYTE"},
          "X509SubjectName": {"type": "string"},
          "X509Certificate": {"$ref": "#/definitions/BYTE"},
          "X509CRL": {"$ref": "#/definitions/BYTE"}},
          "additionalProperties": false},
        "minItems": 1}},
    "required": ["X509DataProperties"],
    "additionalProperties": false
  },
}
```

```
"X509IssuerSerialType": {
  "type": "object",
  "properties": {
    "X509IssuerName": {"type": "string"},
    "X509SerialNumber": {"type": "number"}
  },
  "required": ["X509IssuerName", "X509SerialNumber"],
  "additionalProperties": false
},
"FileData": {
  "type": "object",
  "properties": {
    "restriction": {"$ref": "#/definitions/restriction"},
    "ext-restriction": {"type": "string"},
    "observable-id": {"$ref": "#/definitions/IDtype"},
    "File": {
      "type": "array",
      "items": {"$ref": "#/definitions/File"},
      "minItems": 1}},
  "required": ["File"],
  "additionalProperties": false},
"File": {
  "type": "object",
  "properties": {
    "observable-id": {"$ref": "#/definitions/IDtype"},
    "FileName": {"type": "string"},
    "FileSize": {"type": "number"},
    "FileType": {"type": "string"},
    "URL": {
      "type": "array",
      "items": {"$ref": "#/definitions/URLtype"},
      "minItems": 1},
    "HashData": {"$ref": "#/definitions/HashData"},
    "Signature": {
      "type": "array",
      "items": {"$ref": "#/definitions/SignatureType"},
      "minItems": 1},
    "AssociatedSoftware": {"$ref": "#/definitions/SoftwareType"},
    "FileProperties": {
      "type": "array",
      "items": {"$ref": "#/definitions/ExtensionType"},
      "minItems": 1}},
  "required": [],
  "additionalProperties": false},
"HashData": {
  "type": "object",
  "properties": {
    "scope": {"enum": ["file-contents", "file-pe-section",
```

```
    "file-pe-iat", "file-pe-resource", "file-pdf-object",
    "email-hash", "email-headers-hash", "email-body-hash", "ext-value"]},
  "HashTargetID": {"type": "string"},
  "Hash": {
    "type": "array",
    "items": {"$ref": "#/definitions/Hash"},
    "minItems": 1},
  "FuzzyHash": {
    "type": "array",
    "items": {"$ref": "#/definitions/FuzzyHash"},
    "minItems": 1}},
  "required": ["scope"],
  "additionalProperties": false},
  "Hash": {
    "type": "object",
    "properties": {
      "DigestMethod": {"$ref": "#/definitions/DigestMethodType"},
      "DigestValue": {"$ref": "#/definitions/DigestValueType"},
      "CanonicalizationMethod":
        {"$ref": "#/definitions/CanonicalizationMethodType"},
      "Application": {"$ref": "#/definitions/SoftwareType"}},
    "required": ["DigestMethod", "DigestValue"],
    "additionalProperties": false},
  "CanonicalizationMethodType": {
    "type": "object",
    "properties": {
      "value": {"type": "string"},
      "Algorithm": {"$ref": "#/definitions/URLtype"}
    },
    "required": ["Algorithm"],
    "additionalProperties": false
  },
  "FuzzyHash": {
    "type": "object",
    "properties": {
      "FuzzyHashValue": {
        "type": "array",
        "items": {"$ref": "#/definitions/ExtensionType"},
        "minItems": 1},
      "Application": {"$ref": "#/definitions/SoftwareType"},
      "AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
    "required": ["FuzzyHashValue"],
    "additionalProperties": false},
  "Indicator": {
    "type": "object",
    "properties": {
      "restriction": {"$ref": "#/definitions/restriction",
        "default": "private"},

```



```
"ext-restriction": {"type": "string"},
"IndicatorID": {"$ref": "#/definitions/IndicatorID"},
"AlternativeIndicatorID": {
  "type": "array",
  "items": {"$ref": "#/definitions/AlternativeIndicatorID"},
  "minItems": 1},
"Description": {
  "type": "array",
  "items": {"$ref": "#/definitions/MLStringType"},
  "minItems": 1},
"StartTime": {"$ref": "#/definitions/DATETIME"},
"EndTime": {"$ref": "#/definitions/DATETIME"},
"Confidence": {"$ref": "#/definitions/Confidence"},
"Contact": {
  "type": "array",
  "items": {"$ref": "#/definitions/Contact"},
  "minItems": 1},
"Observable": {"$ref": "#/definitions/Observable"},
"uid-ref": {"$ref": "#/definitions/IDREFType"},
"IndicatorExpression": {
  "$ref": "#/definitions/IndicatorExpression"},
"IndicatorReference": {
  "$ref": "#/definitions/IndicatorReference"},
"NodeRole": {
  "type": "array",
  "items": {"$ref": "#/definitions/NodeRole"},
  "minItems": 1},
"AttackPhase": {
  "type": "array",
  "items": {"$ref": "#/definitions/AttackPhase"},
  "minItems": 1},
"Reference": {
  "type": "array",
  "items": {"$ref": "#/definitions/Reference"},
  "minItems": 1},
"AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
"allof": [
  {"required": ["IndicatorID"]},
  {"oneOf": [
    {"required": ["Observable"]},
    {"required": ["uid-ref"]},
    {"required": ["IndicatorExpression"]},
    {"required": ["IndicatorReference"]}]}],
"additionalProperties": false},
"IndicatorID": {
  "type": "object",
  "properties": {
    "id": {"type": "string"},
```

```
    "name": {"type": "string"},
    "version": {"type": "string"}},
    "required": ["id", "name", "version"],
    "additionalProperties": false},
  "AlternativeIndicatorID": {
    "type": "object",
    "properties": {
      "restriction": {"$ref": "#/definitions/restriction",
        "default": "private"},
      "ext-restriction": {"type": "string"},
      "IndicatorReference": {
        "type": "array",
        "items": {"$ref": "#/definitions/IndicatorReference"},
        "minItems": 1}},
    "required": ["IndicatorReference"],
    "additionalProperties": false},
  "Observable": {
    "type": "object",
    "properties": {
      "restriction": {"$ref": "#/definitions/restriction",
        "default": "private"},
      "ext-restriction": {"type": "string"},
      "System": {"$ref": "#/definitions/System"},
      "Address": {"$ref": "#/definitions/Address"},
      "DomainData": {"$ref": "#/definitions/DomainData"},
      "EmailData": {"$ref": "#/definitions/EmailData"},
      "Service": {"$ref": "#/definitions/Service"},
      "WindowsRegistryKeysModified": {
        "$ref": "#/definitions/WindowsRegistryKeysModified"},
      "FileData": {"$ref": "#/definitions/FileData"},
      "CertificateData": {"$ref": "#/definitions/CertificateData"},
      "RegistryHandle": {"$ref": "#/definitions/RegistryHandle"},
      "RecordData": {"$ref": "#/definitions/RecordData"},
      "EventData": {"$ref": "#/definitions/EventData"},
      "Incident": {"$ref": "#/definitions/Incident"},
      "Expectation": {"$ref": "#/definitions/Expectation"},
      "Reference": {"$ref": "#/definitions/Reference"},
      "Assessment": {"$ref": "#/definitions/Assessment"},
      "DetectionPattern": {"$ref": "#/definitions/DetectionPattern"},
      "HistoryItem": {"$ref": "#/definitions/HistoryItem"},
      "BulkObservable": {"$ref": "#/definitions/BulkObservable"},
      "AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
      "oneOf": [
        {"required": ["System"]},
        {"required": ["Address"]},
        {"required": ["DomainData"]},
        {"required": ["EmailData"]},
        {"required": ["Service"]},
```

```

    { "required": [ "WindowsRegistryKeysModified" ] },
    { "required": [ "FileData" ] },
    { "required": [ "CertificateData" ] },
    { "required": [ "RegistryHandle" ] },
    { "required": [ "RecordData" ] },
    { "required": [ "EventData" ] },
    { "required": [ "Incident" ] },
    { "required": [ "Expectation" ] },
    { "required": [ "Reference" ] },
    { "required": [ "Assessment" ] },
    { "required": [ "DetectionPattern" ] },
    { "required": [ "HistoryItem" ] },
    { "required": [ "BulkObservable" ] },
    { "required": [ "AdditionalData" ] } ],
  "additionalProperties": false,
  "BulkObservable": {
    "type": "object",
    "properties": {
      "type": { "enum": [ "asn", "atm", "e-mail", "ipv4-addr", "ipv4-net",
        "ipv4-net-mask", "ipv6-addr", "ipv6-net", "ipv6-net-mask",
        "mac", "site-uri", "domain-name", "domain-to-ipv4",
        "domain-to-ipv6", "domain-to-ipv4-timestamp",
        "domain-to-ipv6-timestamp", "ipv4-port", "ipv6-port",
        "windows-reg-key", "file-hash", "email-x-mailer",
        "email-subject", "http-user-agent", "http-request-url",
        "mutex", "file-path", "user-name", "ext-value" ] },
      "ext-type": { "type": "string" },
      "BulkObservableFormat": {
        "$ref": "#/definitions/BulkObservableFormat" },
      "BulkObservableList": { "type": "string" },
      "AdditionalData": { "$ref": "#/definitions/ExtensionTypeList" } },
    "required": [ "BulkObservableList" ],
    "additionalProperties": false,
  "BulkObservableFormat": {
    "type": "object",
    "properties": {
      "Hash": { "$ref": "#/definitions/Hash" },
      "AdditionalData": { "$ref": "#/definitions/ExtensionTypeList" } },
    "required": [],
    "additionalProperties": false,
  "IndicatorExpression": {
    "type": "object",
    "properties": {
      "operator": { "enum": [ "not", "and", "or", "xor" ], "default": "and" },
      "ext-operator": { "type": "string" },
      "IndicatorExpression": {
        "type": "array",
        "items": { "$ref": "#/definitions/IndicatorExpression" },

```

```
    "minItems": 1},
  "Observable": {
    "type": "array",
    "items": {"$ref": "#/definitions/Observable"},
    "minItems": 1},
  "uid-ref": {
    "type": "array",
    "items": {"$ref": "#/definitions/IDREFTType"},
    "minItems": 1},
  "IndicatorReference": {
    "type": "array",
    "items": {"$ref": "#/definitions/IndicatorReference"},
    "minItems": 1},
  "Confidence": {"$ref": "#/definitions/Confidence"},
  "AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
  "required": [],
  "additionalProperties": false},
"IndicatorReference": {
  "type": "object",
  "properties": {
    "uid-ref": {"$ref": "#/definitions/IDREFTType"},
    "euid-ref": {"type": "string"},
    "version": {"type": "string"}},
  "required": [],
  "additionalProperties": false},
"AttackPhase": {
  "type": "object",
  "properties": {
    "AttackPhaseID": {
      "type": "array",
      "items": {"type": "string"},
      "minItems": 1},
    "URL": {
      "type": "array",
      "items": {"$ref": "#/definitions/URLtype"},
      "minItems": 1},
    "Description": {
      "type": "array",
      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1},
    "AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
  "required": [],
  "additionalProperties": false}},
"title": "IODEF-Document",
"description": "JSON schema for IODEF-Document class",
"type": "object",
"properties": {
  "version": {"type": "string"},
```

```
"lang": {"$ref": "#/definitions/lang"},
"format-id": {"type": "string"},
"private-enum-name": {"type": "string"},
"private-enum-id": {"type": "string"},
"Incident": {
  "type": "array",
  "items": {"$ref": "#/definitions/Incident"},
  "minItems": 1},
"AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
"required": ["version", "Incident"],
"additionalProperties": false}
```

Figure 9: JSON schema

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