

MILE
Internet-Draft
Intended status: Standards Track
Expires: May 21, 2020

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November 18, 2019

JSON binding of IODEF
draft-ietf-mile-jsoniodef-11

Abstract

The Incident Object Description Exchange Format defined in RFC 7970 provides an information model and a corresponding XML data model for exchanging incident and indicator information. This draft gives implementers and operators an alternative format to exchange the same information by defining an alternative data model implementation in JSON and its encoding in CBOR.

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1. Introduction

The Incident Object Description Exchange Format (IODEF) [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.

IODEF documents are structured and thus suitable for machine processing. They will streamline incident response operations. Another well-used and structured format that is suitable for machine processing is JavaScript Object Notation (JSON) [RFC8259]. To facilitate the automation of incident response operations, IODEF documents should support JSON representation and its encoding in Concise Binary Object Representation (CBOR) [RFC7049].

This document defines an alternate implementation of the IODEF UML information model by specifying a JavaScript Object Notation (JSON) data model using Concise Data Definition Language (CDDL) [RFC8610] 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", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119][RFC8174] when, and only when, they appear in all capitals, as shown here.

2. IODEF Data Types

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, see Section 2.2.1
REAL	Section 2.2	"number" per [RFC8259]
CHARACTER	Section 2.3	"string" per [RFC8259]
STRING	Section 2.3	"string" per [RFC8259]
ML_STRING	Section 2.4	see Section 2.2.2
BYTE	Section 2.5.1	"string" per [RFC8259]
BYTE[]	Section 2.5.1	"string" per [RFC8259]
HEXBIN	Section 2.5.2	"string" per [RFC8259]
HEXBIN[]	Section 2.5.2	"string" per [RFC8259]
ENUM	Section 2.6	see Section 2.2.3
DATETIME	Section 2.7	"string" per [RFC8259]
TIMEZONE	Section 2.8	"string" per [RFC8259]
PORTLIST	Section 2.9	"string" per [RFC8259]
POSTAL	Section 2.10	ML_STRING, Section 2.2.2
PHONE	Section 2.11	"string" per [RFC8259]
EMAIL	Section 2.12	"string" per [RFC8259]
URL	Section 2.13	"string" per [RFC8259]
ID	Section 2.14	"string" per [RFC8259]
IDREF	Section 2.14	"string" per [RFC8259]
SOFTWARE	Section 2.15	see Section 2.2.4
STRUCTUREDINFO	[RFC 7203]	see Section 2.2.5
EXTENSION	Section 2.16	see Section 2.2.6

Figure 1: JSON Data Types

IODEF Data Type	CBOR Data Type	CDDL prelude [RFC8610]
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)
DATE TIME	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. Integer

An integer is a subset of "number" type of JSON, which represents signed digits encoded in Base 10. The definition of this integer is "[minus] int" in [RFC8259] Section 6 manner.

2.2.2. 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
}

```

Note that some pieces of supplementary information are provided folloedb by "#" in figures throughout this document, but these are not a valid syntax in JSON.

2.2.3. Enum

Enum is an ordered list of acceptable string values. Each value has a representative keyword. Within the data model, the enumerated type keywords are used as attribute values.

2.2.4. 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 Uniform Resource Locator (URL) [RFC3986], 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
}

```

2.2.5. 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", "RawData", and "Reference" elements. An example for embedding a structured ID is shown below.

```
"StructuredInfo": {
  "SpecID": "urn:ietf:params:xml:ns:mile:cwe:3.3",          # ENUM
  "ContentID": "CWE-89"                                    # STRING
}
```

When embedding the raw data, base64 encoding defined in Section 4 of [RFC4648] SHOULD be used for encoding the data, as shown below.

```
"StructuredInfo": {
  "SpecID": "urn:ietf:params:xml:ns:mile:mmdef:1.2",      # ENUM
  "RawData": "<<<strings encoded with base64>>>"        # BYTE
}
```

2.2.6. 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?	3.1

	Incident+ AdditionalData*	
Incident	purpose ext-purpose? status? ext-status? lang? restriction? ext-restriction? observable-id? IncidentID AlternativeID? RelatedActivity* DetectTime? StartTime? EndTime? RecoveryTime? ReportTime? GenerationTime Description* Discovery* Assessment* Method* Contact+ EventData* Indicator* History? AdditionalData*	3.2
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?	3.6

	Description* AdditionalData*	
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
Weakness (TBD)	restriction? ext-restriction?	
Reference	observable-id? ReferenceName? URL* Description*	3.11.1
Assessment	occurrence? 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*	3.17

Node	DomainData* Address* PostalAddress? Location* Counter*	3.18
Address	value category ext-category? vlan-name? vlan-num? observable-id?	3.18.1
NodeRole	category ext-category? Description*	3.18.2
Counter	value type ext-type? unit ext-unit? meaning? duration? ext-duration?	3.18.3
DomainData	system-status ext-system-status? domain-status ext-domain-status? observable-id? Name DateDomainWasChecked? RegistrationDate? ExpirationDate? RelatedDNS* Nameservers* DomainContacts?	3.19
Nameserver	Server Address*	3.19.1
DomainContacts	SameDomainContact? Contact+	3.19.2
Service	ip-protocol? observable-id?	

	ServiceName? Port? Portlist? ProtoCode? ProtoType? ProtoField? ApplicationHeaderField* EmailData? Application?	3.20
ServiceName	IANAService? URL* Description*	3.20.1
EmailData	observable-id? EmailTo* EmailFrom? EmailSubject? EmailX-Mailer? EmailHeaderField* EmailHeaders? EmailBody? EmailMessage? HashData* Signature*	3.21
RecordData	restriction? ext-restriction? observable-id? DateTime? Description* Application? RecordPattern* RecordItem* URL* FileData* WindowsRegistryKeysModified* CertificateData* AdditionalData*	3.22.1
RecordPattern	type ext-type? offset? offsetunit? ext-offsetunit? instance? value	3.22.2

WindowsRegistryKeysModified	observable-id? Key+	3.23
Key	registryaction? ext-registryaction? observable-id? KeyName KeyValue?	3.23.1
CertificateData	restriction? ext-restriction? observable-id? Certificate+	3.24
Certificate	observable-id? X509Data Description*	3.24.1
FileData	restriction? ext-restriction? observable-id? File+	3.25
File	observable-id? FileName? FileSize? FileType? URL* HashData? Signature* AssociatedSoftware? FileProperties*	3.25.1
HashData	scope HashTargetID? Hash* FuzzyHash*	3.26
Hash	DigestMethod DigestValue CanonicalizationMethod? Application?	3.26.1
FuzzyHash	FuzzyHashValue+ Application? AdditionalData*	3.26.2
Indicator	restriction?	

	ext-restriction? IndicatorID AlternativeIndicatorID* Description* StartTime? EndTime? Confidence? Contact* Observable? uid-ref? IndicatorExpression? IndicatorReference? NodeRole* AttackPhase* Reference* AdditionalData*	3.29
IndicatorID	id name version	3.29.1
AlternativeIndicatorID	restriction? ext-restriction? IndicatorID+	3.29.2
Observable	restriction? ext-restriction? System? Address? DomainData? Service? EmailData? WindowsRegistryKeysModified? FileData? CertificateData? RegistryHandle? RecordData? EventData? Incident? Expectation? Reference? Assessment? DetectionPattern? HistoryItem? BulkObservable? AdditionalData*	3.29.3
BulkObservable	type?	

	ext-type? BulkObservableFormat? BulkObservableList AdditionalData*	3.29.4
BulkObservableFormat	Hash? AdditionalData*	3.29.5
IndicatorExpression	operator? ext-operator? IndicatorExpression* Observable* uid-ref* IndicatorReference* Confidence? AdditionalData*	3.29.6
IndicatorReference	uid-ref? euid-ref? version?	3.29.7
AttackPhase	AttackPhaseID* URL* Description* AdditionalData*	3.29.8

Figure 3: IODEF Classes

3.2. Mapping between JSON and XML IODEF

- o Attributes and elements of each class in XML IODEF document are both presented as JSON attributes in JSON IODEF document, and the order of their appearances is ignored.
- 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 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 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 Signature, X509Data, and RawData are encoded with base64 and are represented as string (BYTE type) in JSON IODEF documents.
- o EmailBody represents an whole message body including MIME structure in the same manner defined in [RFC7970]. In case of an email composed of MIME multipart, the EmailBody contains multiple body parts separated by boundary strings.
- o The "ipv6-net-mask" type attribute of BulkObservable class remains available for the backward compatibility purpose, but the use of this attribute is not recommended because IPV6 does not use netmask any more.

4. Examples

This section provides examples of IODEF documents. These examples do not represent the full capabilities of the data model or 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 4: A Minimal Example 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)
    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)
        496E636964656E7444944             # "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)
    323031352D30372D31385430393A3030303A30302D30353A3030
                                # "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 5: 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": "domain-name",
        "BulkObservableList": "kj290023j09r34.example.com"
      }
    }
  } ]
} ]
}

```

Figure 6: 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"
  6B          # text(11)
    646F6D61696E2D6E616D65 # "domain-name"
  72          # text(18)
    42756C6B4F627365727661626C654C697374
                                # "BulkObservableList"
  78 1A        # text(26)
    6B6A32393030323336A30397233342E6578616D706C652E636F6D
                                # "kj290023j09r34.example.com"

```

Figure 7: 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
    (Description: [+ MLStringType] // DetectionConfiguration: [+ text])
    Application: SoftwareType
}
```

```
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: [+ BYTE]
}
```

```
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: BYTE
  ? Description: [+ MLStringType]
}

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: [+ BYTE]
  ? 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: BYTE
  DigestValue: BYTE
  ? CanonicalizationMethod: BYTE
  ? Application: SoftwareType
}
```

```
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
  IndicatorID: [+ IndicatorID]
}

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: [+ IDREFType]
  ? IndicatorReference: [+ IndicatorReference]
  ? Confidence: Confidence
  ? AdditionalData: [+ ExtensionType]
}

IndicatorReference = {
  (uid-ref: IDREFType // euid-ref: text)
  ? version: text
}

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

```

Figure 8: Data Model in CDDL

6. IANA Considerations

This document does not require any IANA actions.

7. Security Considerations

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

8. Acknowledgments

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

9. References

9.1. Normative References

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9.2. Informative References

[jsonschema]

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 9: CDDL Prelude mapping in JSON

Appendix B. The IODEF Data Model (JSON Schema)

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

```
{ "$schema": "http://json-schema.org/draft-04/schema#",
  "definitions": {
    "action": { "enum": [ "nothing", "contact-source-site",
      "contact-target-site", "contact-sender", "investigate",
      "block-host", "block-network", "block-port", "rate-limit-host",
      "rate-limit-network", "rate-limit-port", "redirect-traffic",
      "honeypot", "upgrade-software", "rebuild-asset", "harden-asset",
      "remediate-other", "status-triage", "status-new-info",
      "watch-and-report", "training", "defined-coa", "other",
      "ext-value" ] },
    "duration": { "enum": [ "second", "minute", "hour", "day", "month",
      "quarter", "year", "ext-value" ] },
    "SpecID": {
      "enum": [ "urn:ietf:params:xml:ns:mile:mndef:1.2", "private" ] },
    "lang": {
      "type": "string", "pattern": "^$|[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"},
"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": {"$ref": "#/definitions/ExtensionTypeList"}}},
"Contact": {
  "type": "object",
  "properties": {
    "role": {
      "enum": ["creator", "reporter", "admin", "tech", "provider", "user",
              "billing", "legal", "irt", "abuse", "cc", "cc-irt", "leo",
              "vendor", "vendor-support", "victim", "victim-notified",
              "ext-value"]},
      "ext-role": {"type": "string"},
      "type": {"enum": ["person", "organization", "ext-value"]},
      "ext-type": {"type": "string"},
      "restriction": {"$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": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1}},
    "required": ["TelephoneNumber"],
    "additionalProperties": false},
  "Discovery": {
    "type": "object",
    "properties": {
      "source": {
        "enum": ["nidps", "hips", "siem", "av", "third-party-monitoring",
          "incident", "os-log", "application-log", "device-log",
          "network-flow", "passive-dns", "investigation", "audit",
          "internal-notification", "external-notification", "leo",
          "partner", "actor", "unknown", "ext-value"]},
      "ext-source": {"type": "string"},
      "restriction": {"$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}},
    "allOf": [
      {"required": ["Application"]},
      {"oneOf": [
        {"required": ["Description"]},
        {"required": ["DetectionConfiguration"]}]}]},
    "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"}},

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    "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": {
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      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1},
    "Impact": {
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      "items": {
        "properties": {
          "SystemImpact": {"$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",
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    "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": {
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      "items": {"$ref": "#/definitions/MLStringType"},
      "minItems": 1}},
    "required": ["type"],
    "additionalProperties": false},
"TimeImpact": {
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"type": "object",
"properties": {
  "value": {"$ref": "#/definitions/PositiveFloatType"},
  "severity": {"enum": ["low", "medium", "high"]},
  "metric": {"enum": ["labor", "elapsed", "downtime", "ext-value"]},
  "ext-metric": {"type": "string"},
  "duration": {"$ref": "#/definitions/duration", "default": "hour"},
  "ext-duration": {"type": "string"}},
"required": ["value", "metric"],
"additionalProperties": false},
"MonetaryImpact": {
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  "properties": {
    "value": {"$ref": "#/definitions/PositiveFloatType"},
    "severity": {"enum": ["low", "medium", "high"]},
    "currency": {"type": "string"}},
"required": ["value"],
"additionalProperties": false},
"Confidence": {
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  "properties": {
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    "rating": {"enum": ["low", "medium", "high", "numeric", "unknown",
      "ext-value"]},
    "ext-rating": {"type": "string"}},
"required": ["value", "rating"],
"additionalProperties": false},
"History": {
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  "properties": {
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      "default": "private"},
    "ext-restriction": {"type": "string"},
    "HistoryItem": {
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      "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": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"},
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"DateTime": {"$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": {"$ref": "#/definitions/Contact"},
      "minItems": 1},
    "Discovery": {
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      "items": {"$ref": "#/definitions/Discovery"},
      "minItems": 1},
    "Assessment": {"$ref": "#/definitions/Assessment"},
    "Method": {
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      "items": {"$ref": "#/definitions/Method"},
      "minItems": 1},
    "System": {
      "type": "array",
      "items": {"$ref": "#/definitions/System"},
      "minItems": 1},
    "Expectation": {
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      "items": {"$ref": "#/definitions/Expectation"},
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    "minItems": 1},
  "RecordData": {
    "type": "array",
    "items": {"$ref": "#/definitions/RecordData"},
    "minItems": 1},
  "EventData": {
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    "items": {"$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": {
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      "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"},
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              "no-relationship", "unknown", "ext-value"]},

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"ext-ownership": {"type": "string"},
"restriction": {"$ref": "#/definitions/restriction",
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"ext-restriction": {"type": "string"},
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"Node": {"$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": {
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      "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"},
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"required": ["category"],
"additionalProperties": false},
"Counter": {
  "type": "object",
  "properties": {
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    "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": {
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"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},
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"EmailData": {
  "type": "object",
  "properties": {
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    "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": {"$ref": "#/definitions/BYTE"},
      "minItems": 1}}},
  "required": [],
  "additionalProperties": false},
"RecordData": {
  "type": "object",
  "properties": {
    "restriction": {"$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"},
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    "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": {"$ref": "#/definitions/ExtensionTypeList"}},
  "required": [],
  "additionalProperties": false},
"RecordPattern": {
  "type": "object",
  "properties": {
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    "type": {"enum": ["regex", "binary", "xpath", "ext-value"],
             "default": "regex"},
    "ext-type": {"type": "string"},
    "offset": {"type": "number"},
    "offsetunit": {"enum": ["line", "byte", "ext-value"],
                  "default": "line"},
    "ext-offsetunit": {"type": "string"},
    "instance": {"type": "number"}},
  "required": ["value", "type"],
  "additionalProperties": false},
"WindowsRegistryKeysModified": {
  "type": "object",
  "properties": {
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    "Key": {
      "type": "array",
      "items": {"$ref": "#/definitions/Key"},
      "minItems": 1}},
  "required": ["Key"],
  "additionalProperties": false},
"Key": {
  "type": "object",
  "properties": {
    "registryaction": {"enum": ["add-key", "add-value", "delete-key",
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        "delete-value", "modify-key", "modify-value",
        "ext-value"]},
    "ext-registryaction": {"type": "string"},
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    "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": {"$ref": "#/definitions/BYTE"},
        "Description": {
            "type": "array",
            "items": {"$ref": "#/definitions/MLStringType"},
            "minItems": 1}},
        "required": ["X509Data"],
        "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"},
```



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"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": {"$ref": "#/definitions/BYTE"},
  "minItems": 1},
"AssociatedSoftware": {"$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/BYTE"},
    "DigestValue": {"$ref": "#/definitions/BYTE"},
    "CanonicalizationMethod": {"$ref": "#/definitions/BYTE"},
    "Application": {"$ref": "#/definitions/SoftwareType"}},
    "required": ["DigestMethod", "DigestValue"],
    "additionalProperties": false},
"FuzzyHash": {
  "type": "object",
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"properties": {
  "FuzzyHashValue": {
    "type": "array",
    "items": {"$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/IDREFTType"},
    "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": {"$ref": "#/definitions/Reference"},
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    "minItems": 1},
    "AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
  "allof": [
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    {"oneOf": [
      {"required": ["Observable"]},
      {"required": ["uid-ref"]},
      {"required": ["IndicatorExpression"]},
      {"required": ["IndicatorReference"]}]}],
  "additionalProperties": false},
"IndicatorID": {
  "type": "object",
  "properties": {
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    "name": {"type": "string"},
    "version": {"type": "string"}},
  "required": ["id", "name", "version"],
  "additionalProperties": false},
"AlternativeIndicatorID": {
  "type": "object",
  "properties": {
    "restriction": {"$ref": "#/definitions/restriction",
      "default": "private"},
    "ext-restriction": {"type": "string"},
    "IndicatorID": {
      "type": "array",
      "items": {"$ref": "#/definitions/IndicatorID"},
      "minItems": 1}},
  "required": ["IndicatorID"],
  "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"}},
"oneOf": [
  {"required": ["Hash"]},
  {"required": ["AdditionalData"]}
],
"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": {"$ref": "#/definitions/IDREFType"},
      "minItems": 1},
    "IndicatorReference": {
      "type": "array",
      "items": {"$ref": "#/definitions/IndicatorReference"},
      "minItems": 1},
    "Confidence": {"$ref": "#/definitions/Confidence"},
    "AdditionalData": {"$ref": "#/definitions/ExtensionTypeList"}},
  "required": [],
  "additionalProperties": false},
"IndicatorReference": {
  "type": "object",
  "properties": {
    "uid-ref": {"$ref": "#/definitions/IDREFType"},
    "euid-ref": {"type": "string"},
    "version": {"type": "string"}},
  "oneOf": [
    {"required": ["uid-ref"]},
    {"required": ["euid-ref"]}
  ],
  "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 10: JSON schema

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