MINIMAL INTEROPERABILITY MECHANISMS

FOR DUMMIES®

WHY, WHAT AND HOW

There is a lot happening in a city or local community

- **All these systems interact with each other**
- **All of them generate data**
- **All of them require good data to work well**

A local data sharing ecosystem is needed

.. where increasing amounts of useful data about a community are collected and used by the public administration, by business, and by the citizen to help the community work better

The Mission of OASC

"The mission of OASC is to unite cities around the world to build a global market for smart city data and services from the demand side and based on the needs of cities and communities."

(OASC Membership information)

LIVING-IN.EU

The European way of digital transformation in cities and communities

Although a number of initiatives have led to successful innovative digital solutions, their impact on society as a whole remains limited and unevenly distributed across the EU.

The extensive uptake and scaling up of these solutions are crucial to help our cities and communities meet their climate targets and reduce their environmental footprint. It will also encourage citizen participation, and help all types of businesses, including SMEs and start-ups, to prosper.

It is time for all levels of government in the EU to join forces to scale up digital solutions so that at least 300 million Europeans can enjoy a better quality of life by 2025. Encouraging the use of commonly agreed digital solutions among regions, cities and communities will help close the digital divide and reduce inequalities for a stronger territorial cohesion.

Setting up a local data sharing ecosystem is very complicated!

The work of standards organisations

Standards Development Organisations are developing many comprehensive and detailed sets of standards to help cities and communities tackle these issues.

Different standards committees are addressing different of these challenges

If cities would all follow the same sets of detailed standards, then a global market for smart city data and services would happen.

However, ….

1. The Standards landscape is complicated

There are many Standards Development Organisations, each building families of standards from different viewpoints, and these standards are not always compatible with each other.

2. Cities & communities are complicated

- Cities and communities are not monolithic organisations, but consist of many autonomous or semi-autonomous agencies, both public and private, that together provide the services that enable the city to function for the benefit of the citizen.
- It is difficult, if not impossible, to ensure that all agencies in a city follow identical processes and standards.

3. Cities and communities are fiercely independent!

- Cities and communities are fiercely independent and largely make decisions about how they function based on their own resources and priorities.
- They may already be following one family of standards or another.

4. The place of proprietary solutions

Like it or not, many cities and communities and their stakeholder organisations have long-term contracts with technology companies that may require the use of proprietary solutions.

5. The complexity of standards

- Finally, the very detail and complexity of standards may deter smaller cities and communities or those with limited resources from attempting standards implementation. Rather they look for good-enough solutions that they can implement quickly within their existing capabilities.
- It is also true that a few cities have strong technology expertise and resources and can confidently implement standards fully and don’t want to be held back by having to align with cities just starting the process.

The role of OASC – and Living-in.eu

To build a global market for smart city data requires interoperability of solutions between cities and communities around the world.

This must take account of the fact that cities can choose between different technical approaches to tackling any city/community objective, each with its own strengths and weaknesses.

In choosing between different options, cities and communities will make decisions based on their resources, legacy systems, and existing contracts with suppliers.

The key need is therefore to identify:

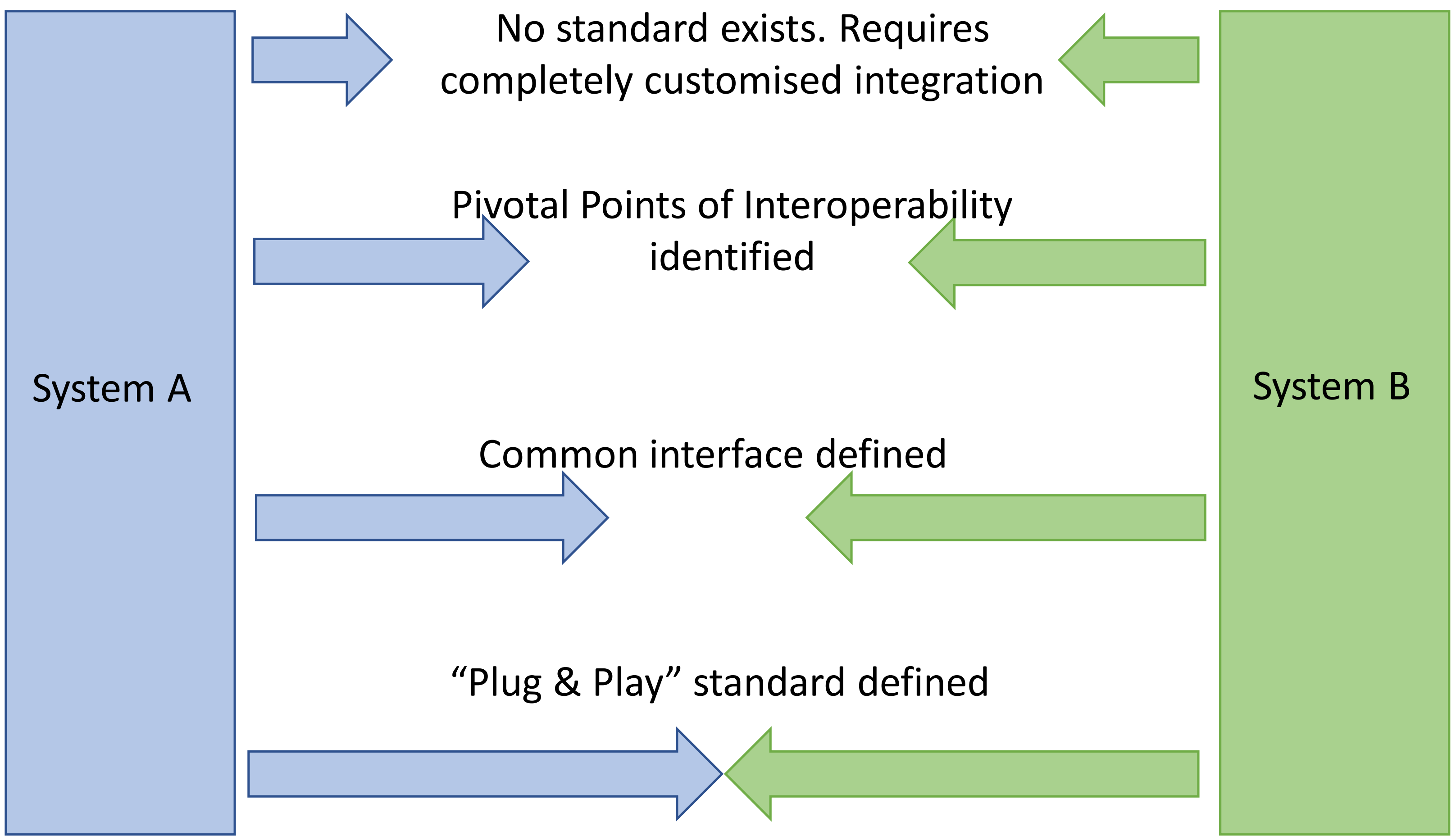
- the range of viable solutions that cities can use to tackle key objectives related to data use; and
- ways to support interoperability between these different solutions.

Why Minimal Interoperability?

Complete interoperability is ideal

However, there is value in achieving at least a level of interoperability.

The greater the level of interoperability, the less work needed for integration.



“Good-enough” interoperability

There is therefore value in an intermediate approach to interoperability; the Minimal Interoperability Mechanisms or MIMs.

These focus on the core requirements needed to achieve city objectives and thus provide a simple but solid starting place.

They also address the variety of technical approaches followed by different sets of standards and proprietary solutions and provide guidance to help align these as far as practical.

In this way, cities and communities can put in place “good enough” mechanisms to get them started in gaining value from potential smart solutions and that address the variety of types of legacy infrastructure and standards ecosystems.

Minimal Interoperability Mechanisms

We are working with our cities and communities to develop the Minimal (but sufficient) Interoperability Mechanisms needed to enable ALL communities to put in place effective local data sharing ecosystems

… and to enable solutions to be shared between cities and communities around the world

Minimal Interoperability Mechanisms

Sufficient interoperability to allow:

- "Good enough" integration of systems
- Development of a viable market – cutting costs, minimising risk and preventing vendor lock-in

Minimal to ensure:

- No unnecessary complexity or time-to-implement
- Minimal resources required

Clearly defined mechanism so that:

- It is easy to determine if a product or service is compliant
- It is easy to determine the steps to implement

We are not re-inventing the wheel!

- Where there are existing authoritative standards, MIMs will point to their core requirements to enable communities to see immediate benefit in developing the local data ecosystem.
- Where there are several competing standards or approaches, MIMs identify Points of Interoperability that will make it easy to link products and services that comply with those different standards/approaches.
- Where there are no existing standards then MIMs can act as Minimum Viable (standards) Products

BENEFITS OF THE MIMs

MINIMAL INTEROPERABILITY MECHANISMS

Market

For Cities and Communities: Choice, flexibility, efficiency, value-for-money, independence, economic development

For Businesses: Scale, agile development/ deployment

Innovation & Policy

For Innovation Consortia: Pre-proposal alignment, post-proposal synergies, agile deployment

For Policymakers: Scale, broad market uptake, avoiding sub-optimisation, agile policy alignment

For all:

Reduced risk, increased investments, innovation

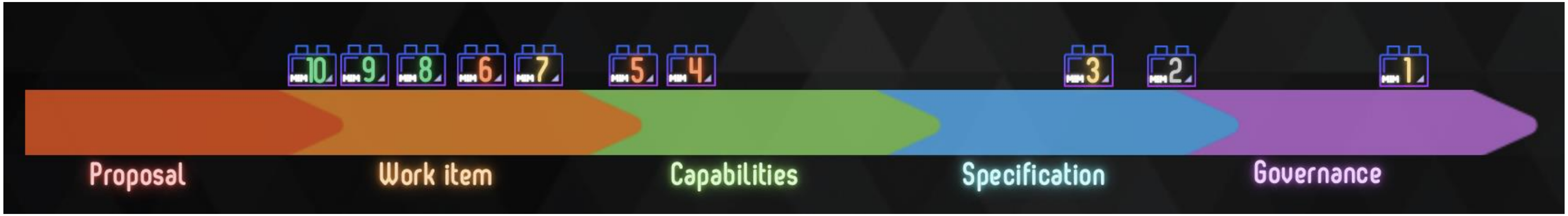
MIMs and MIMs Plus

MIMs are aimed at providing consistent global processes to enable a global market

MIMs Plus set these in the European Policy landscape and are managed through Living-in.EU

The development of the MIMs

STAGES



Governance process

Members and partners → Working Groups → Technical Council

General Assembly ← Board of Directors ← Council of Cities

History and background

MIMs 1, 2 & 3 came from the SynchronCity project, which aimed to develop IoT based services in one city, that could be easily implemented in other cities.

The basis was cities using IoT sensors to collect data focusing on one or more specific issues – air quality, parking etc.

It was designed by cities that were just beginning to use IoT

After that other MIMs were suggested and are now in various states of development

The first three MIMs – developed through SynchroniCity

Table 1: The MIMs Approach

MIM	Name	Point	Description
1	OASC Context Information Management MIM	Context Information Management API	This API allows to access to real-time context information from different cities.
2	OASC Data Models MIM	Shared Data Models	Guidelines and catalogue of common data models in different verticals to enable interoperability for applications and systems among different cities.
3	OASC Ecosystem Transaction Management MIM	Marketplace API	The Marketplace API exposes functionalities such as a catalogue management, ordering management, revenue management, Service Level Agreements (SLA), license management, etc. Complemented by marketplaces for hardware and services.

MIMs 1 & 2

- To gain useful information from IoT sensors, it is important to be able to link data from an IoT device to the context and environment – this air quality sensor is near a busy road, this data was collected in the middle of the night, this data was collected when it was raining … MIM 1
- To be able to implement services developed in one city to in another city, the cities must use consistent data models (machine readable definitions of the things about which the data was being gathered). MIM2

MIM3

- There needs to be a way to find and use the data being gathered in a city
- A lot of the data may have privacy issues, or be commercially valuable, or have security concerns. There needs to be a way to place conditions on who can access that data, and how they can use it.
- There was not time to finish MIM3 in the SynchroniCity project – it was maybe 70% ready, but it is still good enough to be useful

The list of MIMs so far – tackling the requirements of a local data ecosystem

MIM	Subject	Name
MIM1	Context	Context Information Management
MIM2	Data Models	Shared Data Models
MIM3	Contracts	Ecosystem Transactions Management
MIM4	Trust	Personal Data Management
MIM5	Transparency	Fair Artificial Intelligence
MIM6	Security	Security management
MIM7	Places	Geospatial information management
MIM8	Indicators	Ecosystem indicator management
MIM9	Analytics	Data Analytics Management
MIM10	Resources	Resource Impact Assessment

There will be other MIMs later

- The 10 MIMs are designed to cover what is needed for a local data ecosystem that enables datasets/streams to be linked but others may need to be added to make sure all the gaps are filled.
- This is particularly as cities begin to implement data spaces, local digital twins and the CitiVerse, where, for instance, we need to start to consider minimal but sufficient interoperability between models and not just data.

Where we are today

The opportunity of significant new resources

The big change for this year is that several new projects and initiatives have started or are about to start that are funded by the European Commission with tasks that include helping to develop the MIMs.

- This added resource means that we will be able to progress much faster with the MIMs over this coming year.
- However, OASC faces the challenge of coordinating this activity.

Why the Review of the concept & structure?

- The growing experience of using the MIMs has provided useful feedback as to how they can be improved.
- Work on the newer MIMs was leading to inconsistencies in format and structure due to the different types of issues being tackled.
- The MIMs need to be reviewed to ensure that they are fit for purpose for Local Digital Twins, Data Spaces and the CitiVerse.
- **A clearly defined process for developing and structuring the MIMs is needed as much of the work of developing the MIMs will be done with the help of different projects that include people not familiar with the MIMs' history.**

Y.MIM and ITU Study Group 20

Standardising the MIMs format

Introduction

The MIM structure is being developed as an ITU Recommendation within ITU Study Group 20: *IoT and Smart Cities and Communities*.

"This Recommendation defines Minimal Interoperability Mechanisms (MIMs) as a method of specifying sets of requirements that will enable minimal but sufficient interoperability for smart and sustainable cities and communities."

Why work with ITU

We decided to work with this International standardisation Organisation to:

- Get feedback on the MIMs from a group of experts on interoperability related to data management and sharing who have no previous knowledge of the MIMs and so can consider them with a fresh eye.
- Ensure that the MIMs concept and structure are described in a clear and unambiguous way so that they can be properly positioned within the world of standards.

Y.MIM standardises the MIM structure

We decided to focus on standardising the MIM structure and not on the set of MIMs covered by MIMs/MIMs Plus.

We think the MIMs are a good model for any issue where minimal but sufficient interoperability would be valuable for a city – not simply for data sharing ecosystems.

OASC/Living-in.eu can continue to develop the set of MIMs we feel are important, and other agencies can develop MIMs to support issues relevant to them.

The proposed new description of a MIM

A MIM is a description of a common set of requirements that will provide a **Minimal** but sufficient set of capabilities that a city needs to achieve a certain objective, along with a description of the **Mechanisms** by which one or more different technical solutions addresses those requirements.

It also provides guidance to help gain a useful level of **Interoperability** between the different mechanisms that may be used to achieve that set of capabilities.

The aim

There should be a clear link between Objectives, Capabilities, Requirements and Mechanisms so that it can be seen how the Mechanism delivers the Requirements, the Requirements enable the Capabilities, and the Capabilities deliver the Objectives.

There should be an easy way to identify how to enable at least a basic level of interoperability between different mechanisms aimed at delivering the same Objectives

The proposed new format for each MIM

Objectives

The Objectives sets the scope for the MIM by describing at a high level what it aims to achieve.

Capabilities

The Capabilities section describes a minimal but sufficient set of business requirements that will deliver the Objectives to a good-enough level and in a way that is within the resources of most cities.

Requirements

The Requirements section describes the functional and quality requirements that are needed to deliver the agreed minimal set of Capabilities.

Mechanisms

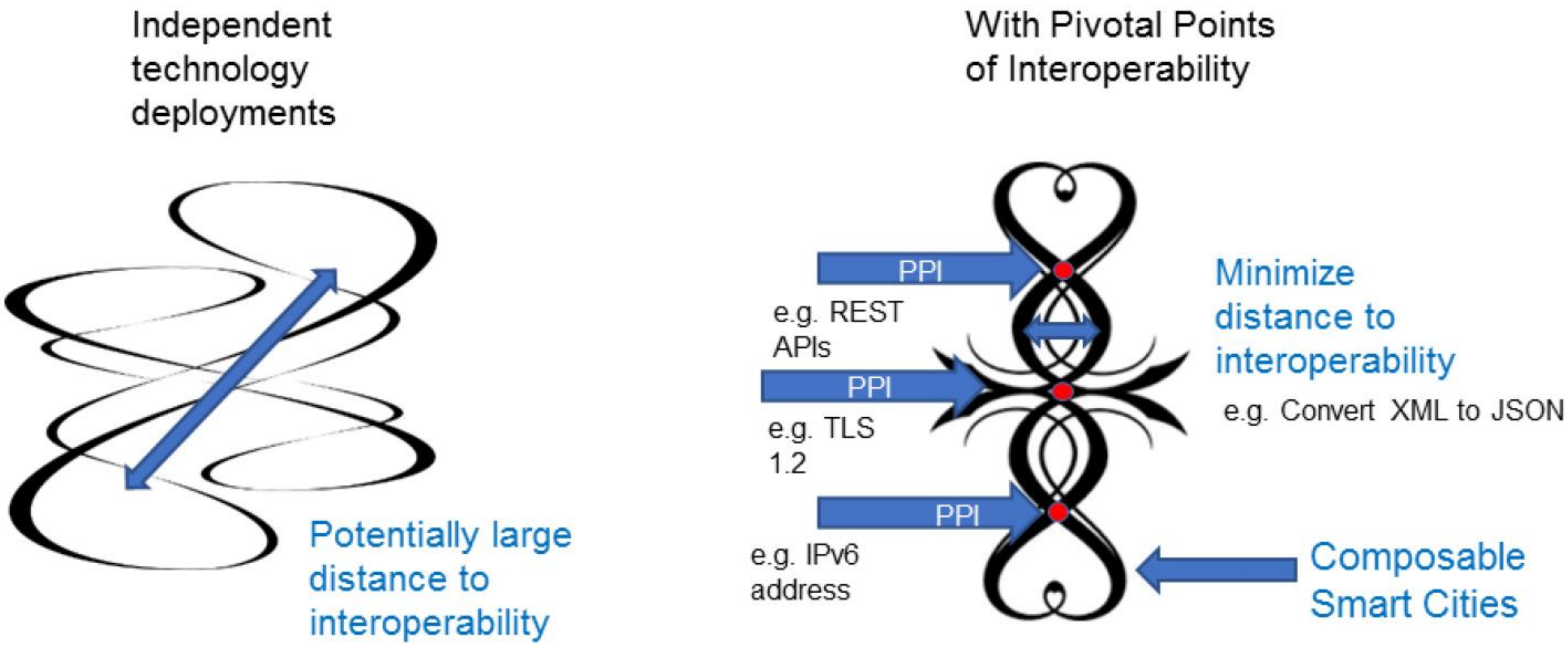
The Mechanisms section identifies technical solutions that address the set of requirements and are already in use by cities and communities. It provides the opportunity for proponents of each solution to describe the mechanisms by which that solution addresses each of the requirements.

Interoperability Guidance

The Interoperability Guidance section uses the descriptions of the Mechanisms provided by different technical solutions to identify where those solutions use common base standards or where processes link to common interfaces.

It then describes options to support interoperability between them, either by describing existing ways of doing this, or by scoping out the work that is needed to develop them.

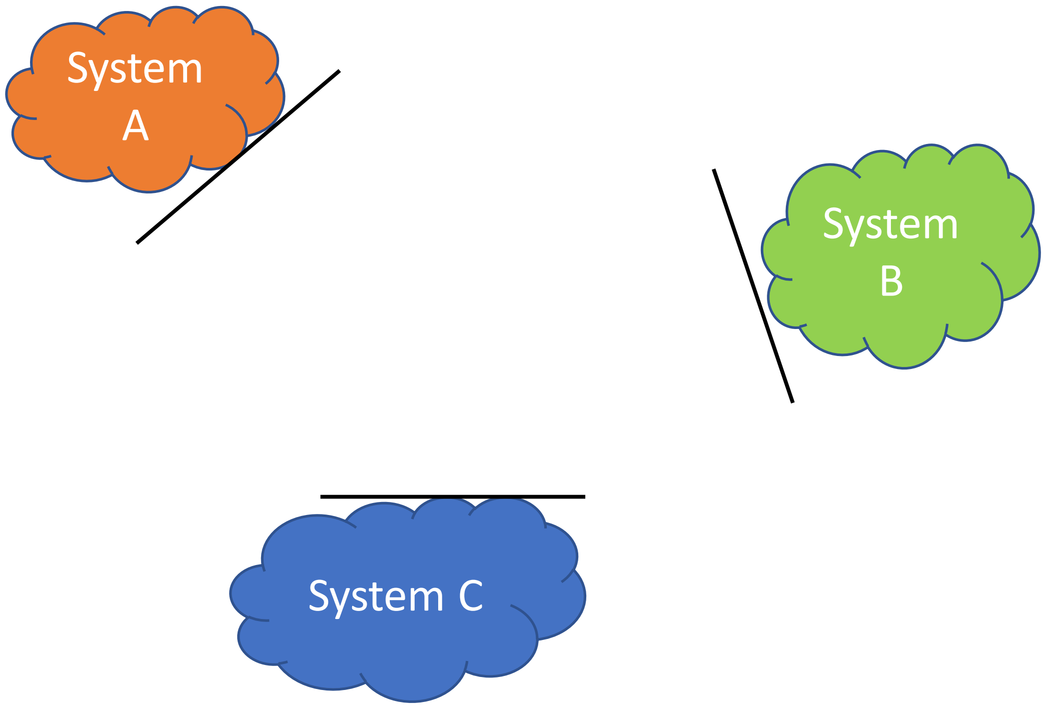
Pivotal Points of Interoperability



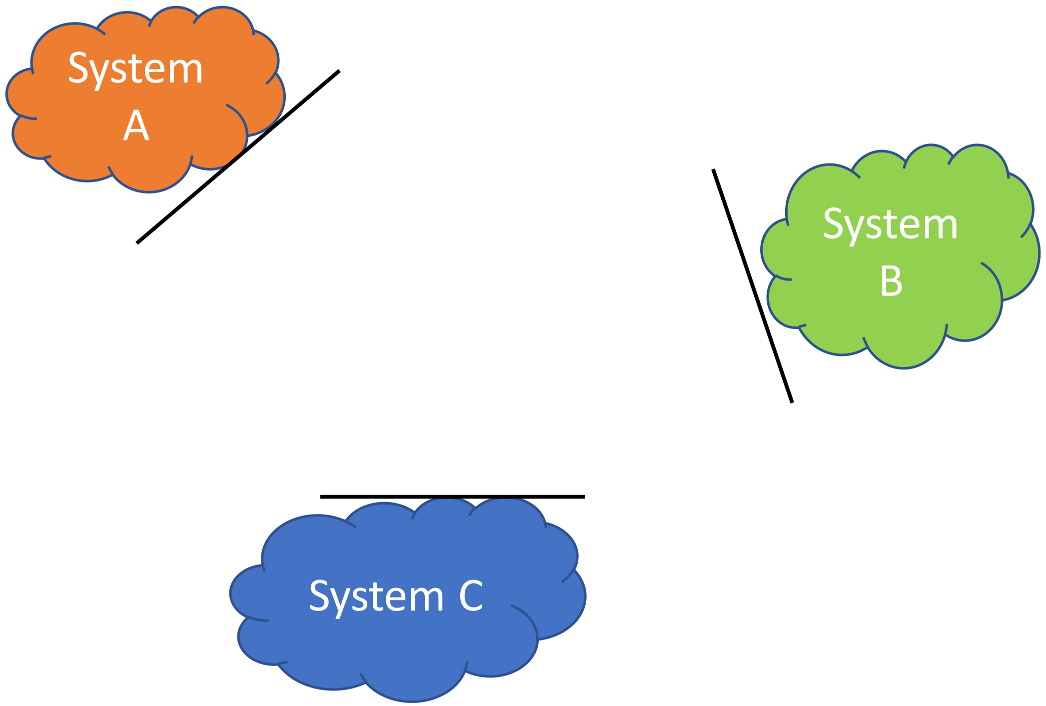
Often within different technology approaches, some concepts and component standards are common. For example, most smart city applications make use of the Internet standards as the technology choice for exchanging information. Such common component standards can be considered as “Pivotal Points of Interoperability” and if these PPI are known, developing interoperability between divergent systems is simplified.

Connectors

Technical Solution 1



Technical Solution 2



Where the different technical solutions need to link to other systems, common Connectors can be developed

The status of the MIMs under the new structure

The present situation

Some of the existing MIMs have been tested to see how they fit into the new structure and the results have been encouraging. However:

- There has only been time to redraft a few of the MIMs into the new structure.
- Even those that have been redrafted are not at a mature stage, and further work and consultation is required.

MIM1 Context information Management

First draft in new format

Objectives:

- To enable information from different systems within a city or community (energy, mobility, education & skills etc.,) and from IoT devices and other data sources, to be brought together using a uniform interface.
- To enable comprehensive and integrated use, sharing, and management of that data.

MIM1 Capabilities and Requirements

Capabilities	Requirements
C1: Applications are able to access data from different sources (cities, communities, vertical solutions).	R1: A uniform interface should be used; the context management API
	R2: Information from all sources should use the same concepts, so called data information models
C2: Applications are able to use both current and historical data, use geospatial querying and be automatically updated when the source data changes.	R3: The uniform interface should support retrieval of current data
	R4: The uniform interface should support retrieval of historical data
	R5: The uniform interface should support geospatial querying
	R6: The uniform interface should support subscription to changes
C3: Applications can discover and retrieve relevant data sources related to their context, including from within larger data sets.	R7: Relevant data sources to any required context (at least location and time period) should be discoverable and retrievable according to their context
	R8: Specific subsets of data relevant to the context should be retrievable from within larger data sets and with default limits and page sizes

MIM1 Requirements and Mechanism NGSI-LD

Requirements	Mechanism NGSI-LD
R1: A uniform interface should be used; the context management API	NGSI-LD API is a uniform context management API that is provided by different context broker applications
R2: Information from all sources should use the same concepts, so called data information models	This is provided through the common NGSI-LD information model, which is the meta model on which the API is based. The (NGSI-LD) world consists of Entities that can have Properties, Relationships etc.
R3: The uniform interface should support retrieval of current data	From an NGSI-LD terminology perspective you would retrieve one or more Entities with their Attributes. You can restrict the Attributes to be returned as part of the Entity to those provided in “attrs”, which is a URI parameter. You can discover all Entities based on their characteristics by specifying their type. **The API call to use is** **GET /entities**
R4: The uniform interface should support retrieval of historical data	Historical data is stored in the Context Broker and accessible in a similar way as the latest data can be retrieved. **The API call to use is** **GET /entities/temporal**
R5: The uniform interface should support geospatial querying	Entities and Context Sources have location properties in GeoJSON. Entities and Context Sources can be geoqueried by specifying a georel relation such as near, within,... **The API call to use is** **GET /entities or** **GET /CSourceRegistrations**
R6: The uniform interface should support subscription to changes	This can be done by posting a Subscription object. **The API call to use is:** **POST /subscriptions/**
R7: Relevant data sources to any required context (at least location and time period) should be discoverable and retrievable according to their context	This can be done using a type-query **The API call to use is** **GET /CSourceRegistrations**
R8: Specific subsets of data relevant to the context should be retrievable from within larger data sets and with default limits and page sizes	NGSI-LD is agnostic to specific pagination mechanisms but requires NGSI-LD Systems to support and define default limits and page sizes

MIM1 Requirements and Mechanism OGC

Requirements	Mechanism OGC
R1: A uniform interface should be used; the context management API	A series of APIs for sensor data (SensorThings API), features (OGC API-Features, WFS), metadata (OGC API-Records) that share the same architectural pattern of the SensorThings API can be used
R2: Information from all sources should use the same concepts, so called data information models	Semantic assets from e.g. INSPIRE as highlighted in MIM-7 that are encoded through different bindings e.g. CityGML, CityJSON, SensorThings API data model, etc.
R3: The uniform interface should support retrieval of current data	Each API in OGC will have a different operation to implement R3, R4 and R5. In particular for OGC/INSPIRE, R5 is very powerful as this is what those services are made to do. Therefore, in order to do this properly, this should be done on a per-standard basis.
R4: The uniform interface should support retrieval of historical data	
R5: The uniform interface should support geospatial querying	
R6: The uniform interface should support subscription to changes	This is currently only supported by SensorThings API through MQTT. The rest of the APIs are synchronous and not subscription-based.
R7: Relevant data sources to any required context (at least location and time period) should be discoverable and retrievable according to their context	Achievable through OpenAPI specifications of APIs, metadata and OWS GetCapabilities for old legacy services. Discoverable through search engine is partially achieved through html encoding of data and API pagination but is still challenging.
R8: Specific subsets of data relevant to the context should be retrievable from within larger data sets and with default limits and page sizes	Through queries. All APIs and legacy support this through different approaches. STA also supports MQTT.

<table>
<tr><th>Requirements</th><th>Mechanism RDF</th></tr>
<tr><td>R1: A uniform interface should be used; the context management API</td><td>A semantic triple, or RDF triple or simply triple, codifies a statement about semantic data in the form of subject–predicate–object expressions, each addressable via a unique URI's.
Context is thus provided automatically using the subject–predicate–object expression.</td></tr>
<tr><td>R2: Information from all sources should use the same concepts, so called data information models</td><td>RDF is the atom of information (whereas ERD models are molecules) with a minimum of structure. Context is provided in the same way as other types of data and/or metadata.

Basic vocabularies are provided by RDFS (RFD Schema) which allows for hierarchy of classes and properties. Additionally, OWL extends RDFS by adding more advanced constructs.

RDF validation against a set of conditions is done through SHACL.

The entire RDF stack is managed in an open process by W3C and ISO.</td></tr>
<tr><td>R3: The uniform interface should support retrieval of current data</td><td rowspan="3">SPARQL is an RDF query language.

Historical data retrieval uses the same pattern as retrieving any other type of data.

Spatial querying is done through GeoSPARQL, managed by the OGC. The GeoSPARQL standard follows a modular design; it comprises several different

components.

- A core component defines top-level RDFS/OWL classes for spatial objects.

- A topology vocabulary component defines RDF properties for asserting and querying topological relations between spatial objects.

- A geometry component defines RDFS data types for serializing geometry data, geometry-related RDF properties, and non-topological spatial query functions for geometry objects.

- A geometry topology component defines topological query functions.

- An RDFS entailment component defines a mechanism for matching implicit RDF triples that are derived based on RDF and RDFS semantics.

- A query rewrite component defines rules for transforming a simple triple pattern that tests a topological relation between two features into an equivalent query involving concrete geometries and topological query functions.</td></tr>
<tr><td>R4: The uniform interface should support retrieval of historical data</td></tr>
<tr><td>R5: The uniform interface should support geospatial querying</td></tr>
<tr><td>R6: The uniform interface should support subscription to changes</td><td>RDF triples follow the same pattern as any distributed Pub/Sub interaction scheme (including MQTT).</td></tr>
<tr><td>R7: Relevant data sources to any required context (at least location and time period) should be discoverable and retrievable according to their context</td><td>Data discoverability and cataloguing done through the DCAT (DCAT is an RDF vocabulary designed to facilitate interoperability between data catalogues published on the Web).</td></tr>
<tr><td>R8: Specific subsets of data relevant to the context should be retrievable from within larger data sets and with default limits and page sizes</td><td>Triples form a loosely coupled distributed dataset and can be retrieved as a graph, based on the query – either for sub-setting or further querying.</td></tr>
</table>

MIM2: Data Models

First draft in new format

Objective

- To support cities and communities to use consistent and machine-readable definitions of all the entities about which data is being captured in a data ecosystem, so that data about any entity can be combined with other data referring to that entity in the confidence that they refer to the same thing

MIM2 Capabilities and Requirements

Capabilities	Requirements
C1: Cities and communities can draw on catalogues of common vocabularies and minimum common data models in different verticals to enable interoperability for applications, and systems.	R1. As far as possible, data models should be taken from a list of standard specifications. Use common concepts and vocabularies.
C2: The data models used in a data ecosystem can be handled by the context management APIs.	R2. All key entities in any data set should be formally defined in a machine-readable way.
	R3. Data models should contain as much information as possible regarding their context.
	R4: Data models should be in a format consistent with MIM1.
C3: Data models based on different standards can be aligned.	R5: Data models should be clearly defined using a consistent process to enable ease of transformation between the different sets of standard data models.
	R6: Translation engines should be developed/identified to enable data models from different standards to be aligned.

MIM2 Mechanisms Semantic Web

Requirements	Mechanisms Semantic Approach
R1. As far as possible, data models should be taken from a list of standard specifications. Use common concepts and vocabularies.	Use an existing ontology, ideally one from the Smart Data Models catalogue, or from the Linked Open Data Cloud.
R2. All key entities in any data set should be formally defined in a machine-readable way.	Semantic Web ontologies are typically serialised in RDF, JSON-LD or Turtle formats, which are machine readable.
R3. Data models should contain as much information as possible regarding their context.	Semantic Web ontologies should be linked together, thus creating a complex web of data where the relations of properties between different ontologies.
R4: Data models should be in a format consistent with MIM1.	
R5: Data models should be clearly defined using a consistent process to enable ease of transformation between the different sets of standard data models.	A governance scheme should be put in place to make sure ontologies are maintained consistently.
R6: Translation engines should be developed/identified to enable data models from different standards to be aligned.	In a semantic web setting, this means linking together different ontologies. This is a task that is often neglected because there is no clean ownership of the “space in between” ontologies.

MIM2 Mechanism Non-Semantic Web

Requirements	Mechanisms Non-Semantic Web Approach
R1. As far as possible, data models should be taken from a list of standard specifications. Use common concepts and vocabularies.	Use a data model that is not technology-specific but rather domain-specific (and non-proprietary), and that has sufficient traction within the industry.
R2. All key entities in any data set should be formally defined in a machine-readable way.	Use common serialisation formats such as JSON, XML or CSV.
R3. Data models should contain as much information as possible regarding their context.	Use mature data models and refrain from defining custom data models for in-house solutions.
R4: Data models should be in a format consistent with MIM1.	
R5: Data models should be clearly defined using a consistent process to enable ease of transformation between the different sets of standard data models.	Data models should be well documented, and any instance must allow automatic validation against the specification, for instance by providing a Schema (XSD) in the case of XML, etc.
R6: Translation engines should be developed/identified to enable data models from different standards to be aligned.	Maintain mapping tables and document similarities with properties in similar or related data models.

MIM2 Interoperability Mechanisms

Interoperability Mechanism 1	**Mechanism Semantic Web Approach**
One issue with interoperability between semantic and non-semantic data models is that semantic models require all instances to have a unique and persistent identifier. Identifiers in a non-semantic setting can use different identification schemes. One way of turning non-semantic identifiers, such as Digital Object Identifiers (DOIs), is by prefixing them with a URI. In case of this approach, one needs to set up a "resolver" service, which can generate URI's for each entity, and allows resolving them to a page (ideally a semantic document) that provides more information about the entity and allows linking it to others.	URI **Mechanism Non-Semantic Web Approach** Digital Object Identifier (DOI) INSPIRE
Interoperability Mechanism 2	**Mechanism Semantic Web Approach**
Another great challenge in using data models is the abundance of existing models, which may describe the same or similar types of information, but do not align correctly.	Where it is not possible to precisely align data models, an ontology service, such as SKOSMOS should be used to enable a "good enough" level of consistency between data models **Mechanism Non-Semantic Approach** ?

MIM4 Interoperability Mechanisms

Example of a Connector

MIM4 Objectives

- To provide technical and other guidance to support cities and communities to put in place the products and services that will enable their citizens to be in control of their personal data within the local data ecosystem.
- To do this in a way that will make it easy to integrate with whatever credible personal data management systems (such as forthcoming EU-registered personal data intermediary services) their citizens may wish to use.

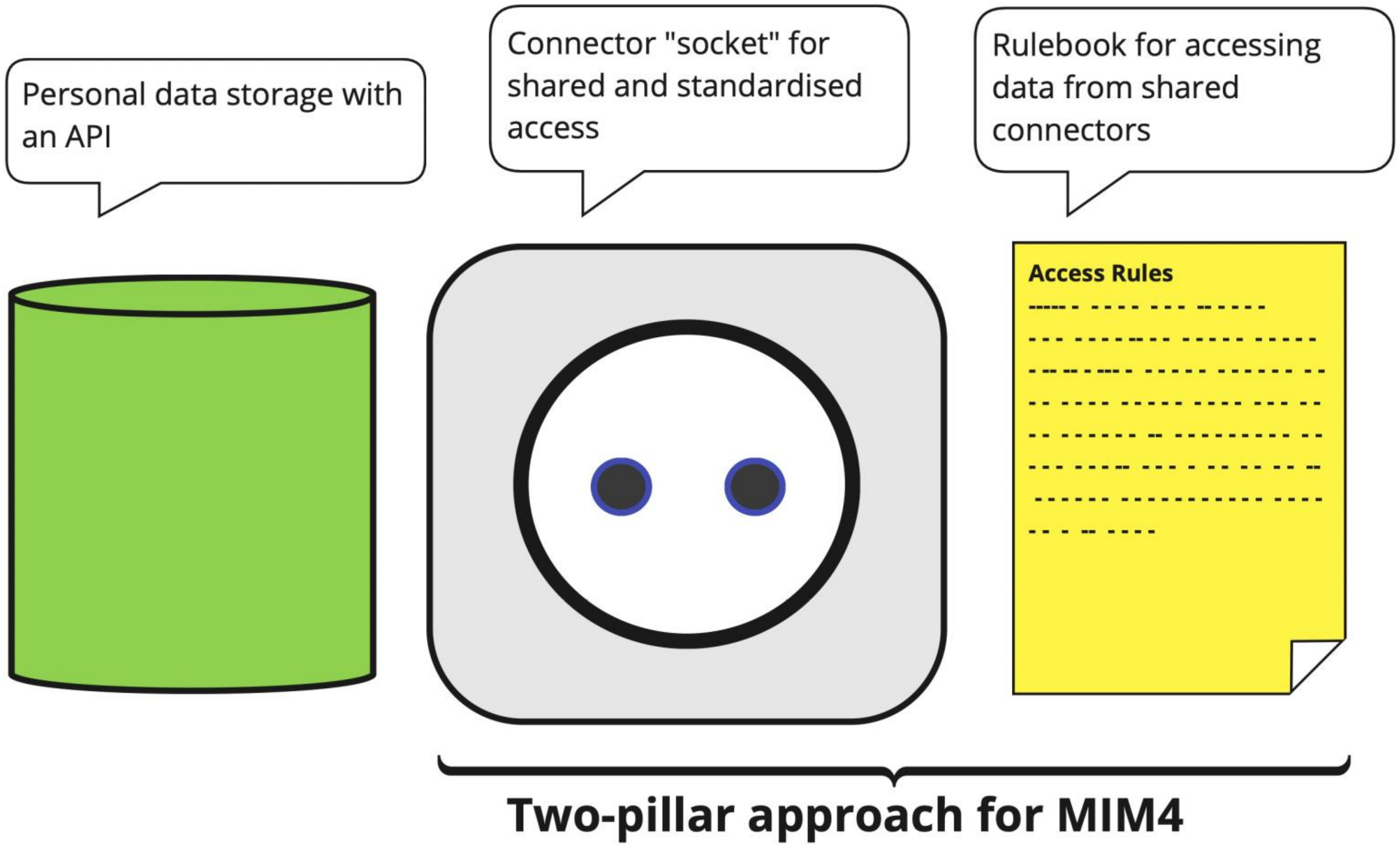
Interoperability Mechanism for Personal Data Management

A detailed proposal for interoperability between Personal Data Intermediaries has been agreed. This proposal has two pillars:

- Pillar 1: One Connector for all Personal Data Intermediaries
- Pillar 2: Legal framework governance

The proposal is described in the paper *"Towards Interoperable Personal Data Management within Smart Cities: Minimum Interoperability Mechanism 4"* that can be accessed at: https://mims.oascities.org/mims/oasc-mim4-trust/references

Interoperability Mechanism for Personal Data Management



You can benefit already

MIMs 1, 2 & 3 are already in widespread use. Any revisions will not undermine any existing provision but simply add more options and greater clarity.

MIMs are being built into the toolkits for data spaces and Local Digital Twins and they will also have a key role in the CitiVerse

Where you can help

We need to:

- Finalise MIMs 1, 2 & 3 in the new format
- Work with Personal Data Intermediaries to finalise MIM4: Personal Data Management
- Work in partnership with CommuniCity and Citycom.ai on MIM5: Fair AI
- Finalise MIM7: Spaces
- Work on Procurement Guidance and Compliance Testing for all of these
- Start work on the other MIMs in the new format

Please get in touch Michael@oascities.org

Questions? Comments?