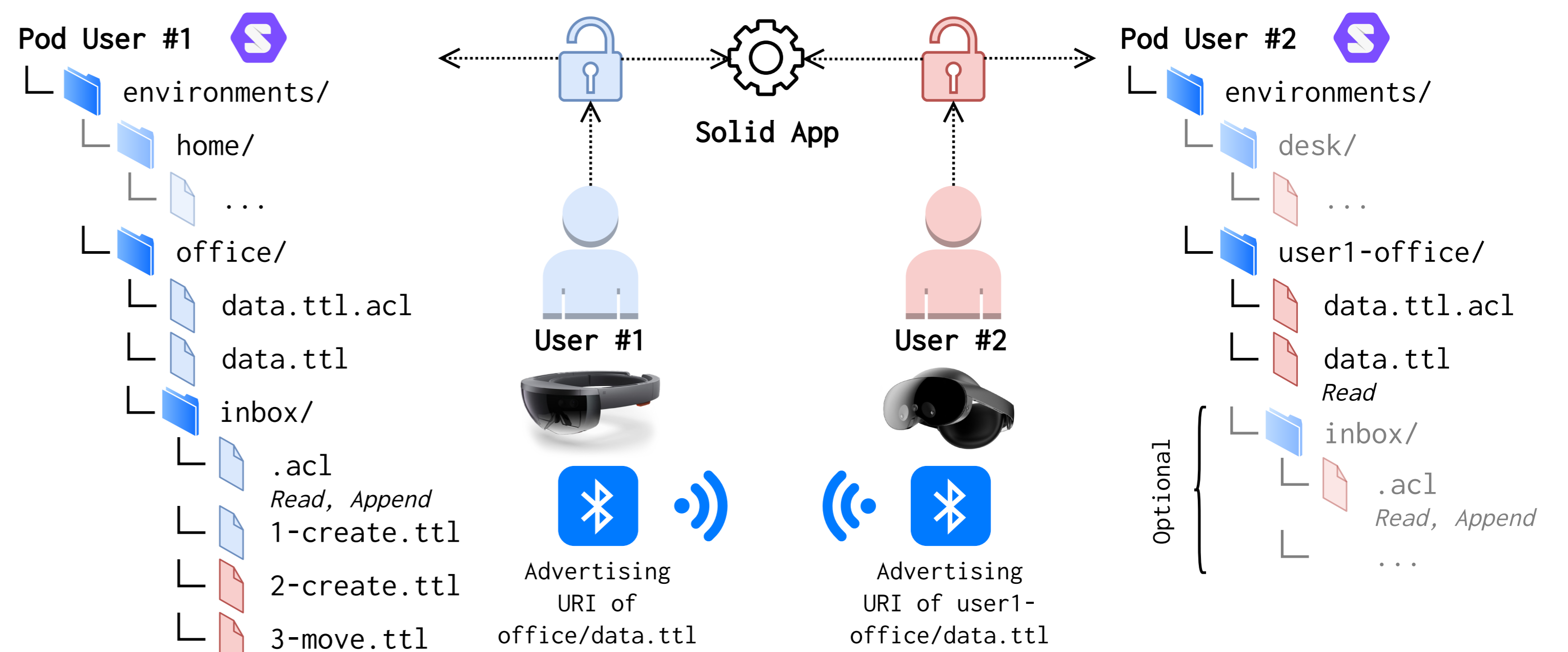


Discoverable and Interoperable Augmented Reality Environments Through Solid Pods



Augmented Reality (AR) environments are physical environments with virtual objects superimposed through AR-enabled devices. These virtual objects can range from simple aesthetic objects such as pictures to superimposed contextual information about physical items. In most modern AR applications, these augmented spaces exist only for the user who created the environment or for proprietary applications that enable multi-user collaboration in the same environment. However, there is a lack of solutions that enable interoperable collaboration in these personal AR spaces, allowing users to share and contribute to an AR space. We propose a solution that enables users to create their personal AR space that can then be discovered by other users who are in physical proximity to this space, enabling them to view or contribute to the augmented space. In addition, we discuss a solution that utilises the same technique to create AR spaces that are bound to a specific room and can be discovered by users who are in close vicinity to these rooms.



Discovery via Semantic Beacons

SemBeacon Advertisement Data (Based on AltBeacon)

Adv Flags	Len	Type	Company ID	Beacon Code	Namespace ID	Instance ID	TX @ 1m	Flags
3B	1B	1B	2B	2B	16B	4B	1B	1B
-	0x1B	0xFF	uint16	0xBEAC	128-bit UUID	32-bit UUID	int8	-

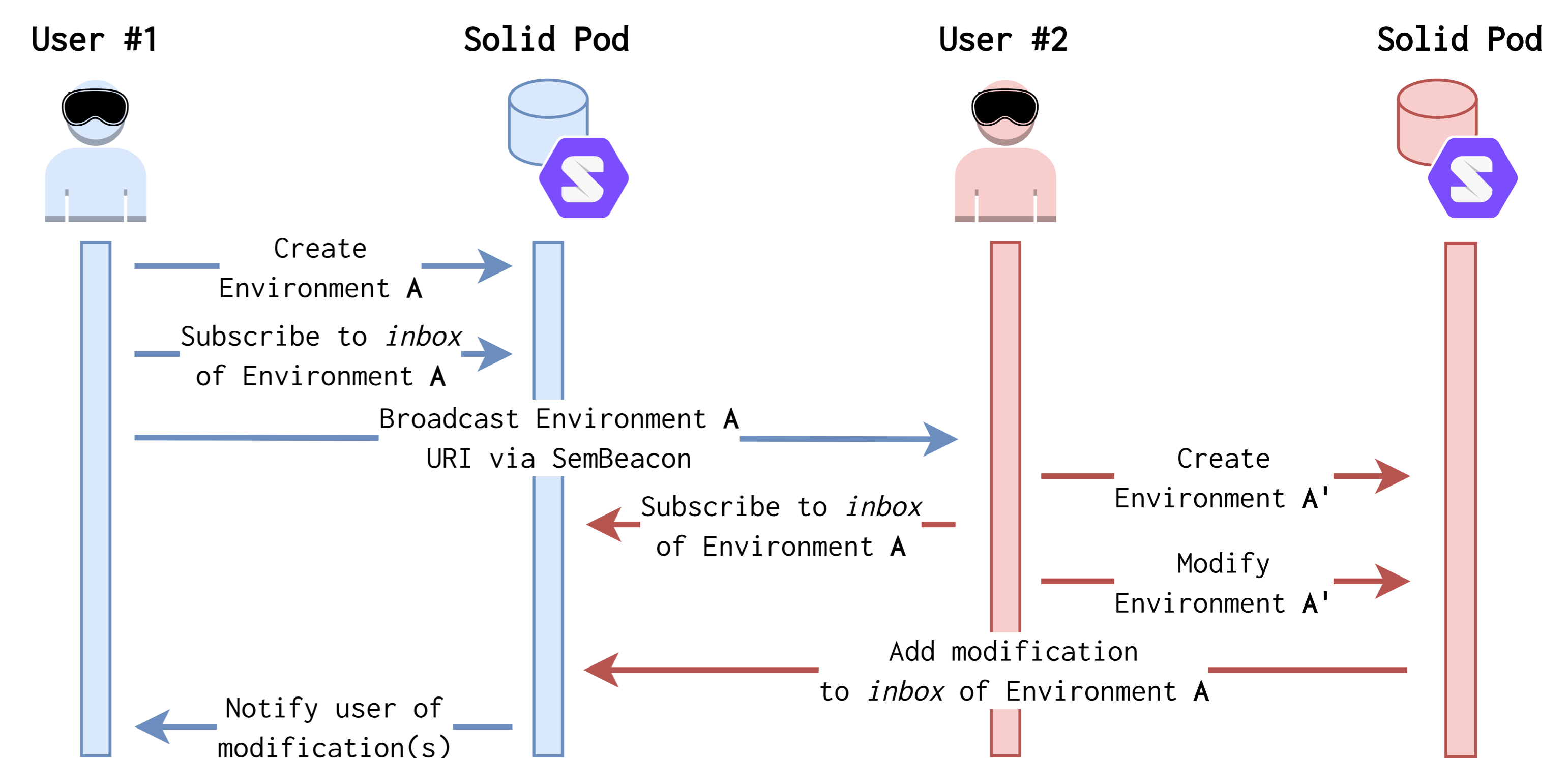
SemBeacon Scan Response Data (Eddystone-URL compatible)

Len	Type	UUID	Frame	TX @ 0m	URI Prefix	Encoded Short Resource URI
1B	1B	2B	1B	1B	1B	0B - 17B
0x??	0x16	0xFEAA	0x10	int8	uint8	uint8[]



M. Van de Wynckel and B. Signer, "SemBeacon: A Semantic Proximity Beacon Solution for Discovering and Detecting the Position of Physical Things," in Proceedings of the 13th International Conference on the Internet of Things, in IoT '23. New York, NY, USA: Association for Computing Machinery, 2024, pp. 9-16. doi: 10.1145/3627050.3627060.

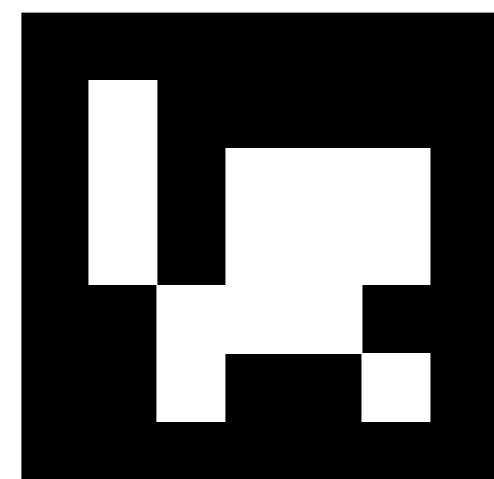
Discovery and Interaction Flow



Vocabularies and Usage

Example of an Aruco marker and virtual earth placed relative to this marker.

```
<> a seas:Room ; rdfs:label "Our Lab"@en ;
    ldp:inbox <./inbox/> ;
    vcard:address [ ... ] .
:table_marker a fidmark:AruCo ;
    poso:hasPosition [ poso:isRelativeTo <> ] ;
    fidmark:hasDictionary fidmark:DICTIONARY_ORIGINAL ;
    fidmark:markerIdentifier 94 ;
    fidmark:hasOrigin fidmark:OriginCenter ;
    fidmark:hasHeight [ a qdt:QuantityValue ;
        qdt:unit unit:Millim ; qdt:numericValue "80"^^xsd:double
    ] ;
    fidmark:hasWidth [ a qdt:QuantityValue ;
        qdt:unit unit:Millim ; qdt:numericValue "80"^^xsd:double
    ] .
```



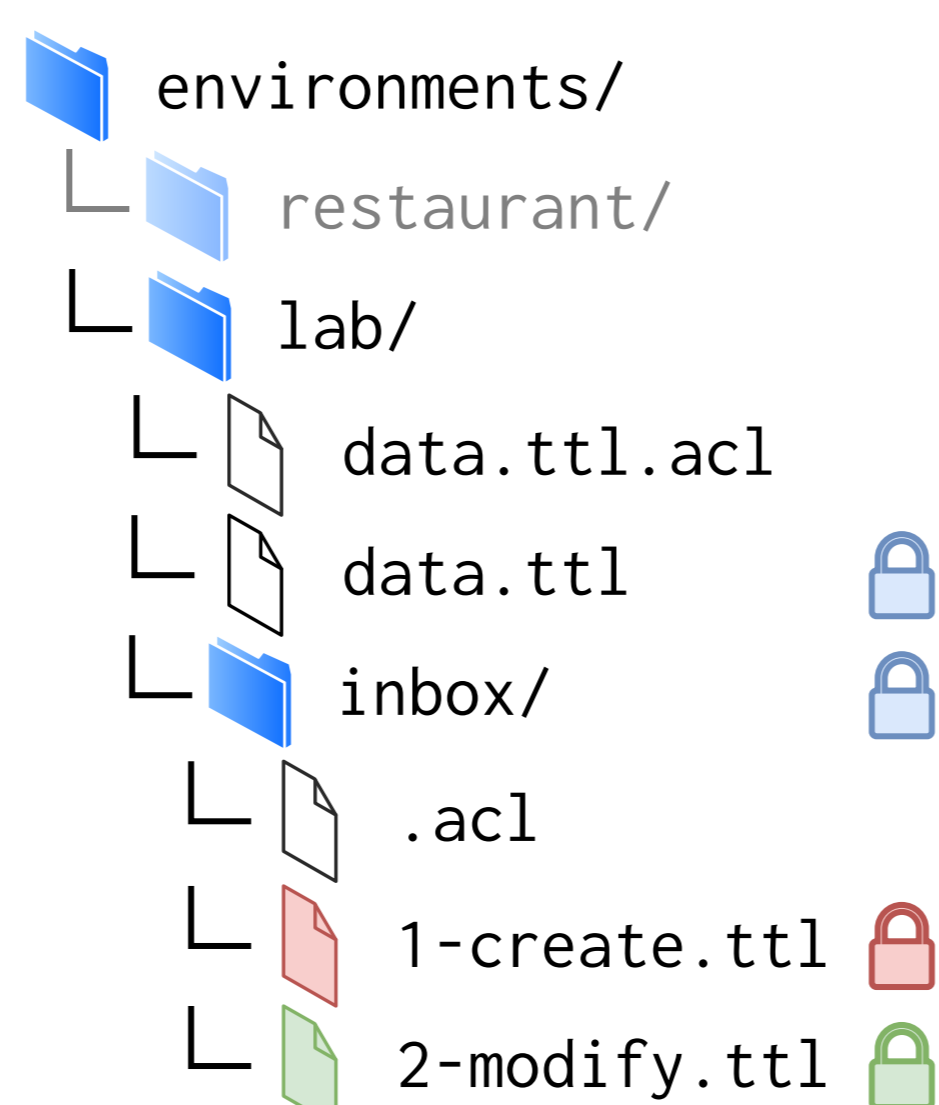
POSO and FidMark are used to position objects and markers. OMG (<https://w3id.org/omg/>) and FOG (<https://w3id.org/fog/>) are used to describe 3D geometries.



```
:earth_object a sosa:FeatureOfInterest, ogc:SpatialObject ;
    poso:hasPosition [ a poso:RelativePosition ;
        poso:isRelativeTo :table_marker ;
        poso:xAxisValue [ a qdt:QuantityValue ; qdt:unit unit:Millim ;
            qdt:numericValue "0"^^xsd:double ] ;
        poso:yAxisValue [ a qdt:QuantityValue ; qdt:unit unit:Millim ;
            qdt:numericValue "0"^^xsd:double ] ;
        poso:zAxisValue [ a qdt:QuantityValue ; qdt:unit unit:Millim ;
            qdt:numericValue "100"^^xsd:double ] ;
        omg:hasGeometry [ a omg:Geometry ;
            fog:asGltf "https://raw.githubusercontent.com/microsoft/mixed-reality-extension-sdk-samples/master/samples/solar-system/public/assets/earth.gltf"^^xsd:anyURI
        ] .
```

Access Control

1. Modifications are stored in the Solid Pod of the user who made the modifications.
2. Changes are referenced in the LDP inbox of the original environment.
3. Each environment can have its own access rights to control who can see virtual objects.
4. Individual modifications and contributions can have their own access rights.



Modification Inbox Events

Modifications are created in the Solid Pod of the person who made the changes. An inbox action (using schema.org) is created to notify the original owner of the environment that a modification has been made. The user of the original environment can then decide to apply this modification.

Actions: schema:CreateAction, schema:TransferAction, schema>DeleteAction

```
@prefix schema: <https://schema.org/> .
@prefix card: <https://{user2}/profile/card#> .
@prefix office: <https://{user2}/environments/user1-office/data.ttl#> .

<> a schema:CreateAction ;
    schema:description "Created a new object 'Earth'"@en ;
    schema:agent <https://ar-app.com/id> ;
    schema:creator card:me ;
    schema:object office:earth_object ; schema:result office:earth_object .
```



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