WoT Graph
as Multiscale Digital Twin
for Cyber-Physical Systems-of-Systems

Dr. G. Privat
Orange Labs, Grenoble, France

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Outline

Viewing the Web of Things as a Graph to capture Complex systems environments

Starting points :

- REST (HATEOAS) graph of WoT nodes as hyperlinked resources
- Graph nodes as Digital Twins of connected devices and non-connected things
- Structural composition graphs as Digital Twins of Cyber-Physical Systems and Systems of Systems

Property graphs as relevant meta-model for CPSS /WoT graph

- Links in the graph match physical connections, are not purely informational abstractions
- CPSS structural graph have an « analog » semantics of their own

System composition as an overlay property graph

Semantic referencing is a complementary overlay RDF graph

Wiewing the WoT as a graph

From :

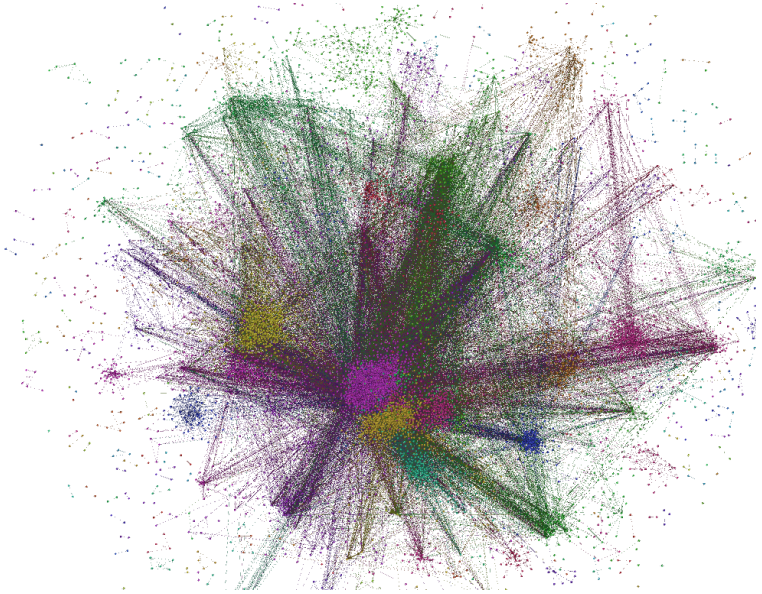
World Wide Web

The WorldWideWeb (W3) is a wide-area hypermedia information retrieval initiative aiming to give universal access to a large universe of documents.

Everything there is online about W3 is linked directly or indirectly to this document, including an executive summary of the project, Mailing lists , Policy , November's W3 news , Frequently Asked Questions .

What's out there?
Pointers to the world's online information, subjects , W3 servers, etc.
Help
on the browser you are using
Software Products
A list of W3 project components and their current state. (e.g. Line Mode ,X11 Viola , NeXTStep , Servers , Tools , Mail robot , Library)
Technical
Details of protocols, formats, program internals etc
Bibliography
Paper documentation on W3 and references.
People
A list of some people involved in the project.
History
A summary of the history of the project.
How can I help ?
If you would like to support the web..
Getting code
Getting the code by anonymous FTP , etc.

to :



From :

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  "@type": ["Thing"],
  "name": "MyLampThing",
  "interaction": [
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          }]
      },
      {
          "@type": ["Action"],
          "name": "toggle",
          "link": [{
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          }]
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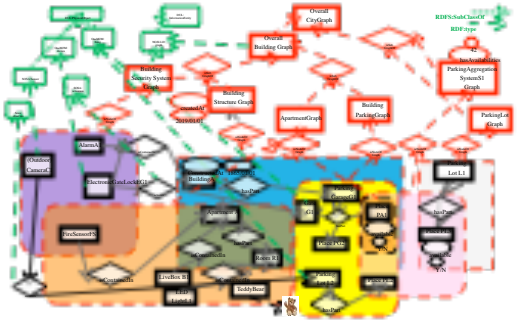
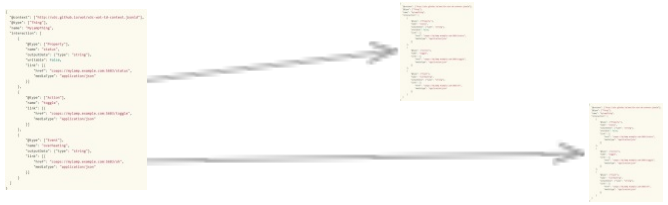
to :



3 foundations for the WoT as a graph

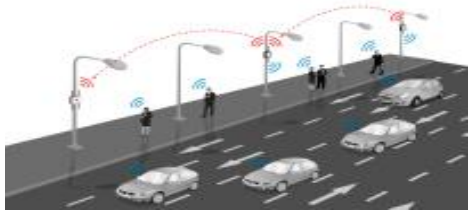
1 hyperlinks (hypermedia controls) between thing resources make up graph



2 nodes as Digital Twins of connected devices *and* non-connected entities

3 structural CPS description as a graph *and* digital twin at system level

Simple CPS graph example



y% congested

hasState

Street A

ConnectsTo

Crossing AB

ConnectsTo

Alley B

70%

hasCoverage

monitors

controlledBy

isActuatorFor

Surveillance Camera A1

Traffic Light TL1

hasState

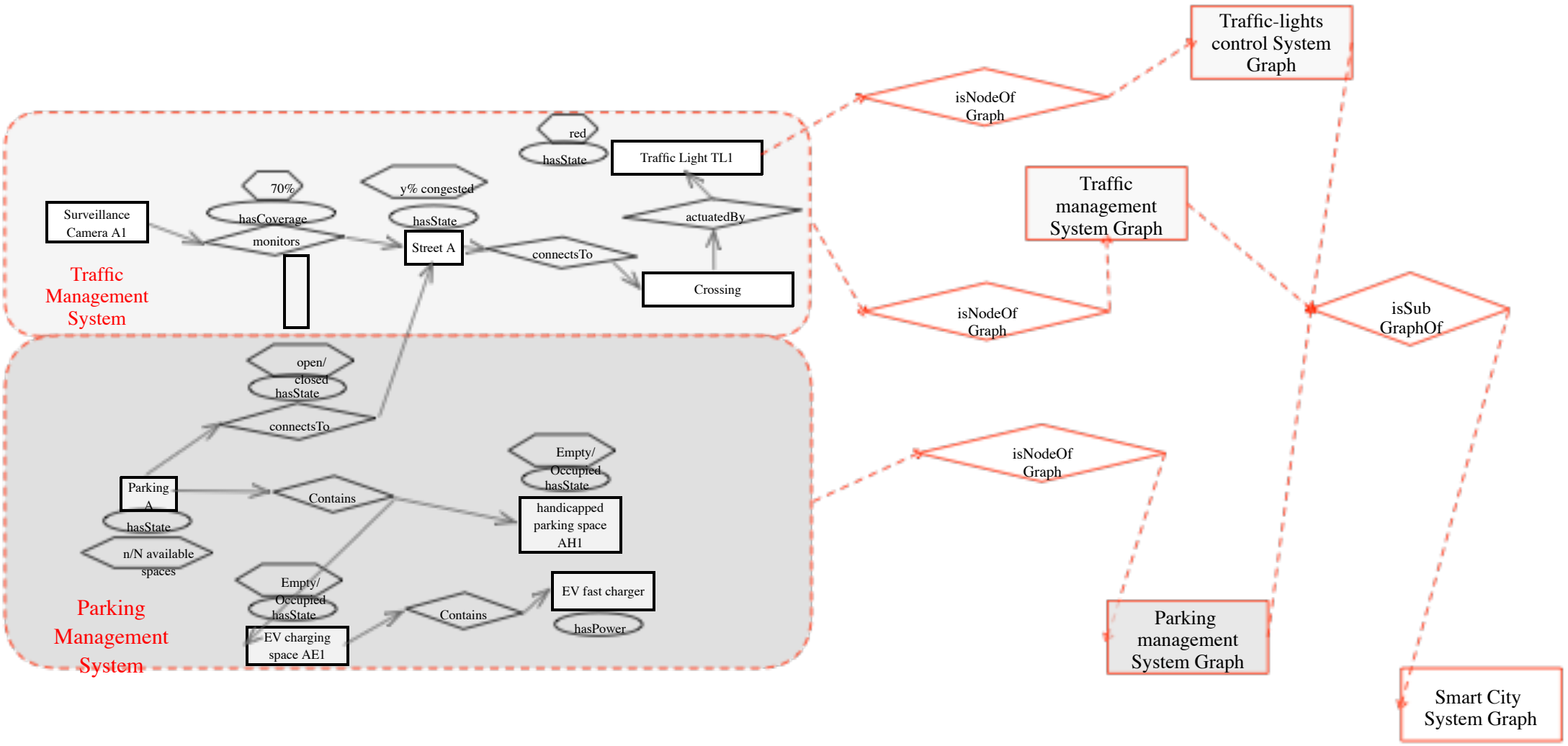
Red/Yellow/Green

Retractable Bollard B1

hasState

Open/closed

System composition as overlay graph



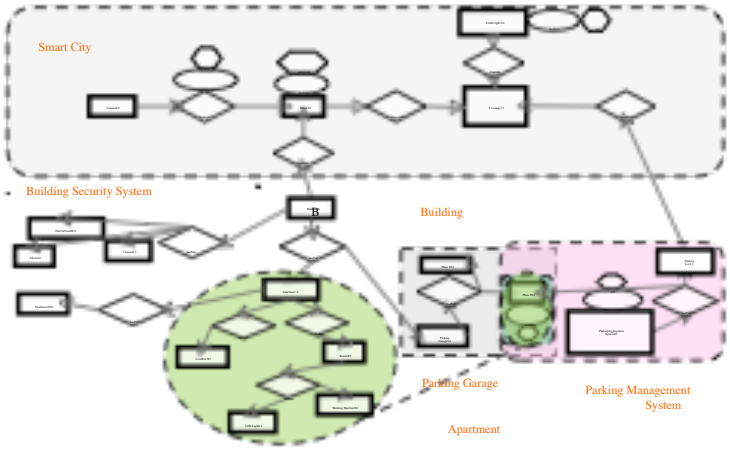
Representing nested Cyber-Physical Systems of Systems

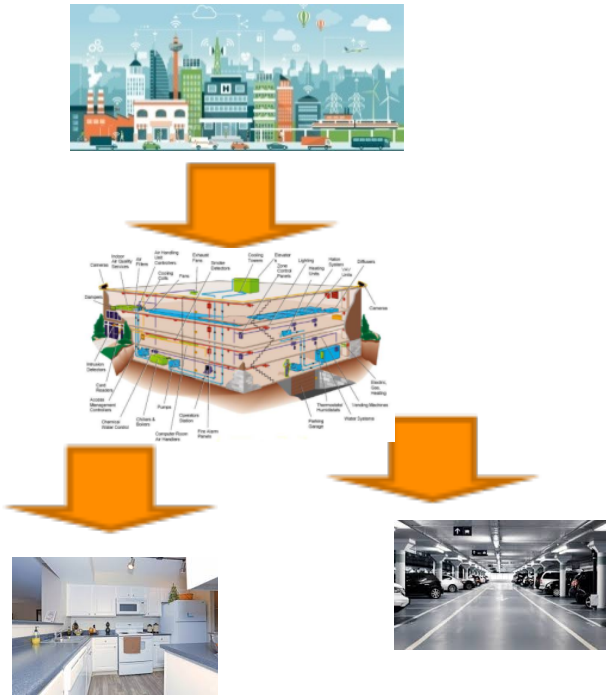
Capturing different *system composition levels* in complex environments

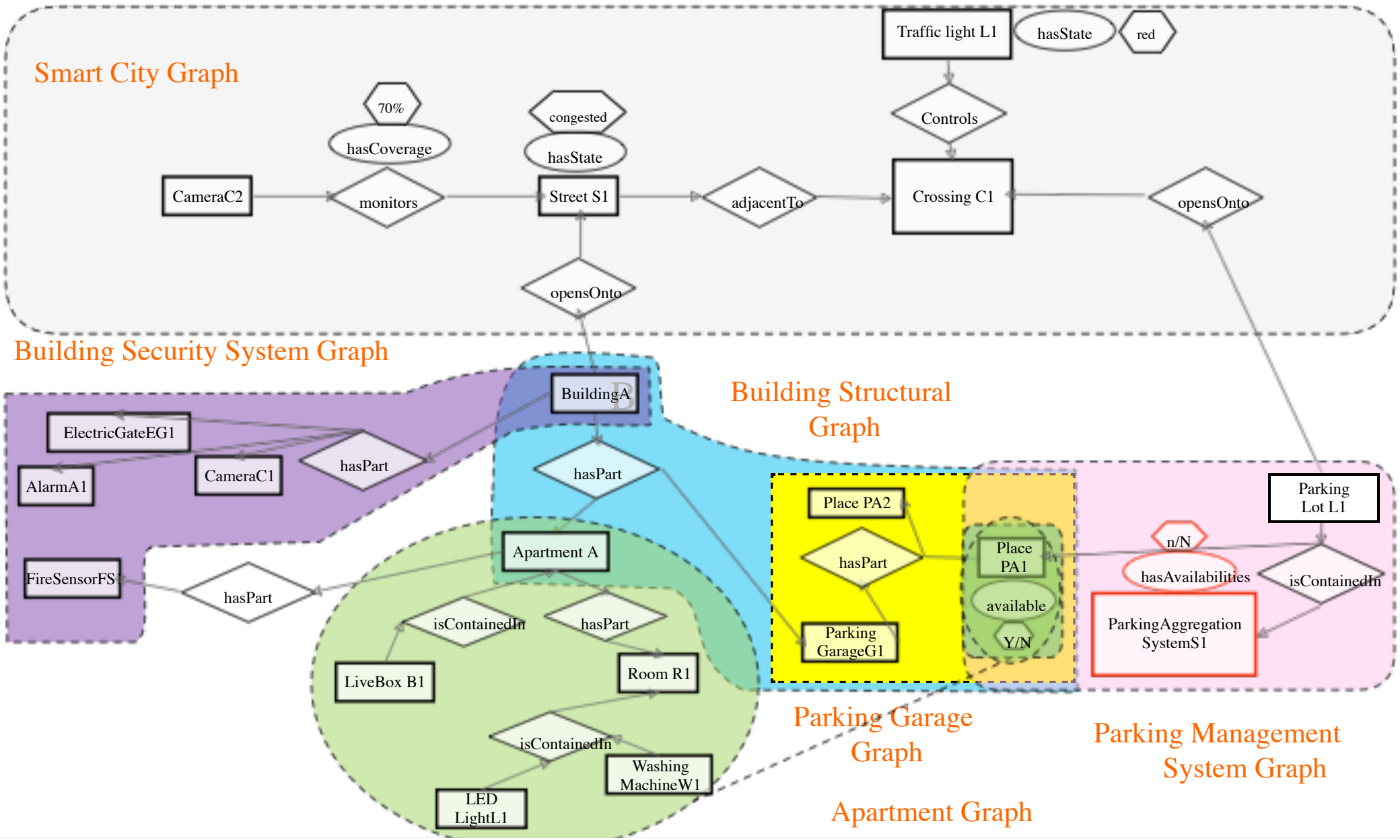
- the building is inside the city, but building entities are not directly city entities
- the apartment is inside the building, but home entities are not directly building entities

Distinguish different *views* of same physical « *plant* »

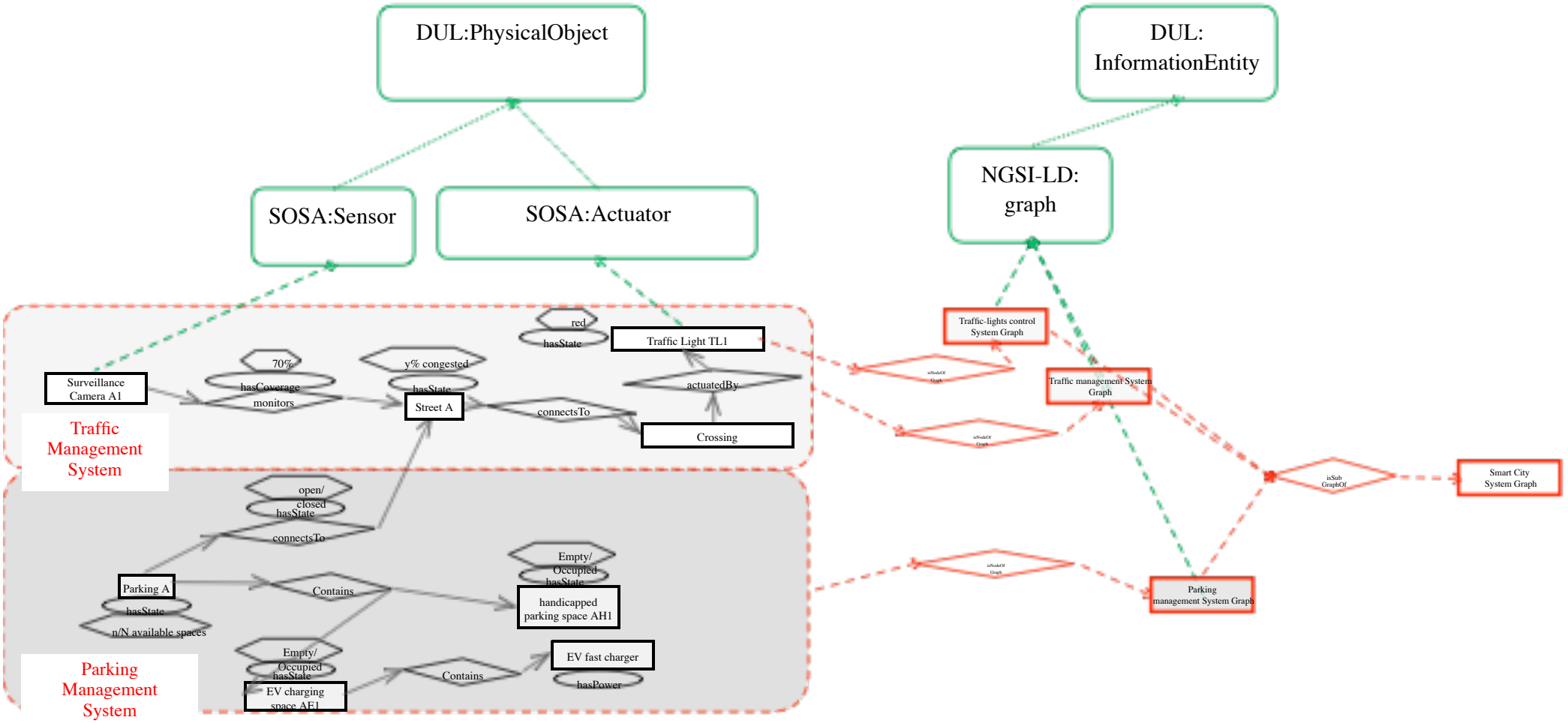
- Supports management of privacy, security & legal ownership issues with corresponding data

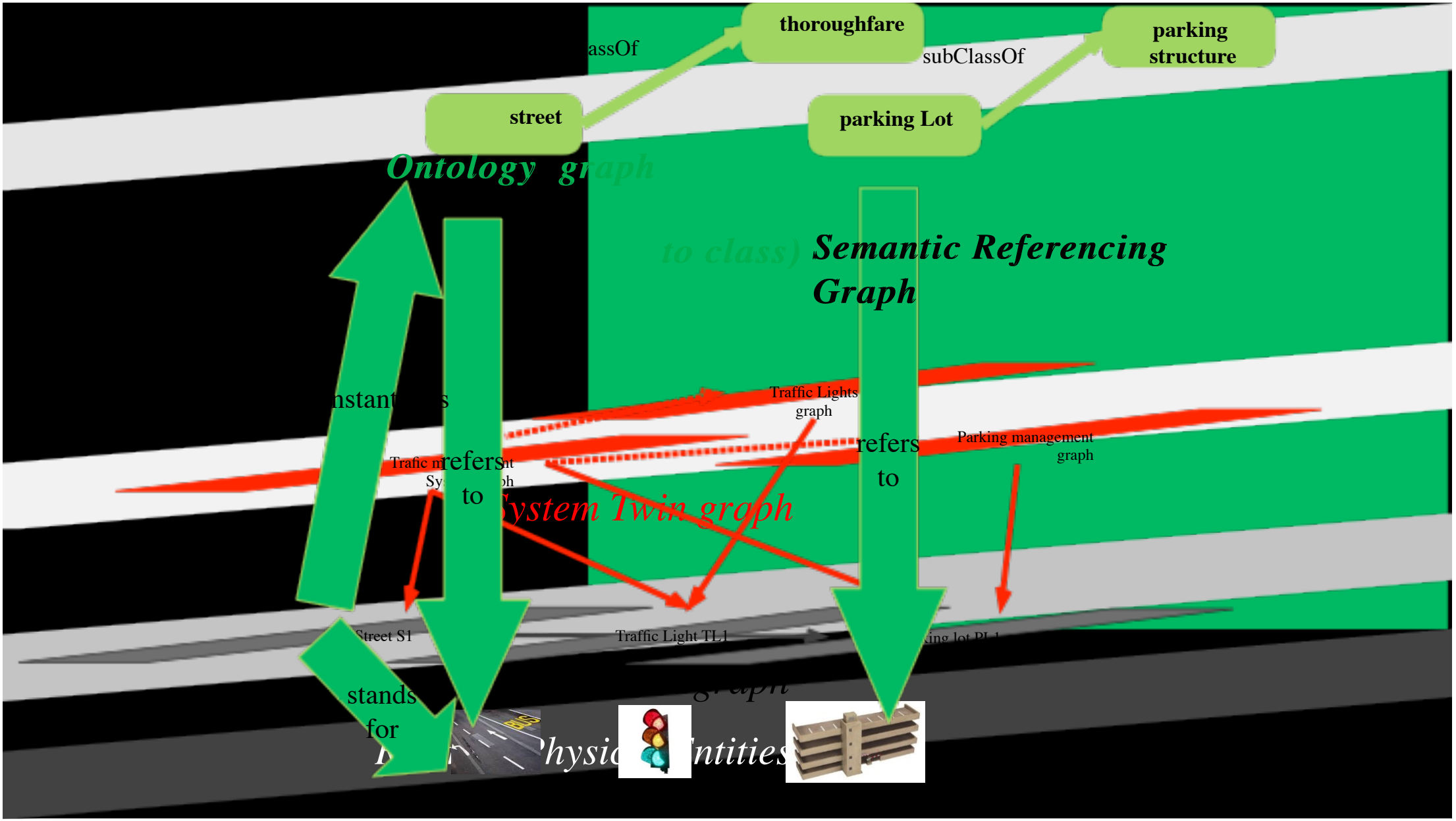





Smart City Graph
Traffic light L1
hasState
red
Controls
70%
hasCoverage
congested
hasState
CameraC2
monitors
Street S1
adjacentTo
Crossing C1
opensOnto
opensOnto
Building Security System Graph
BuildingA
Building Structural Graph
ElectricGateEG1
AlarmA1
CameraC1
hasPart
hasPart
Place PA2
Parking Lot L1
Apartment A
hasPart
Place PA1
n/N
FireSensorFS
hasPart
hasPart
hasAvailabilities
isContainedIn
isContainedIn
hasPart
available
Y/N
ParkingAggregation SystemS1
LiveBox B1
Room R1
Parking GarageG1
isContainedIn
Washing MachineW1
LED LightL1
Parking Garage Graph
Parking Management System Graph
Apartment Graph

Semantic referencing (knowledge graph proper) as an overlay on CPSS graph

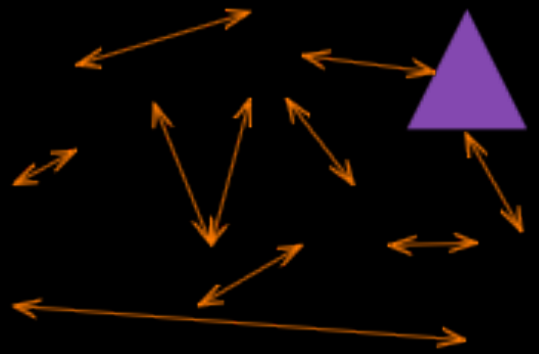



thoroughfare
assOf
subClassOf
parking structure
street
parking Lot
Ontology graph
to class)
Semantic Referencing Graph
Traffic Lights graph
refers to
Parking management graph
refers to
System Twin graph
Street S1
Traffic Light TL1
stands for

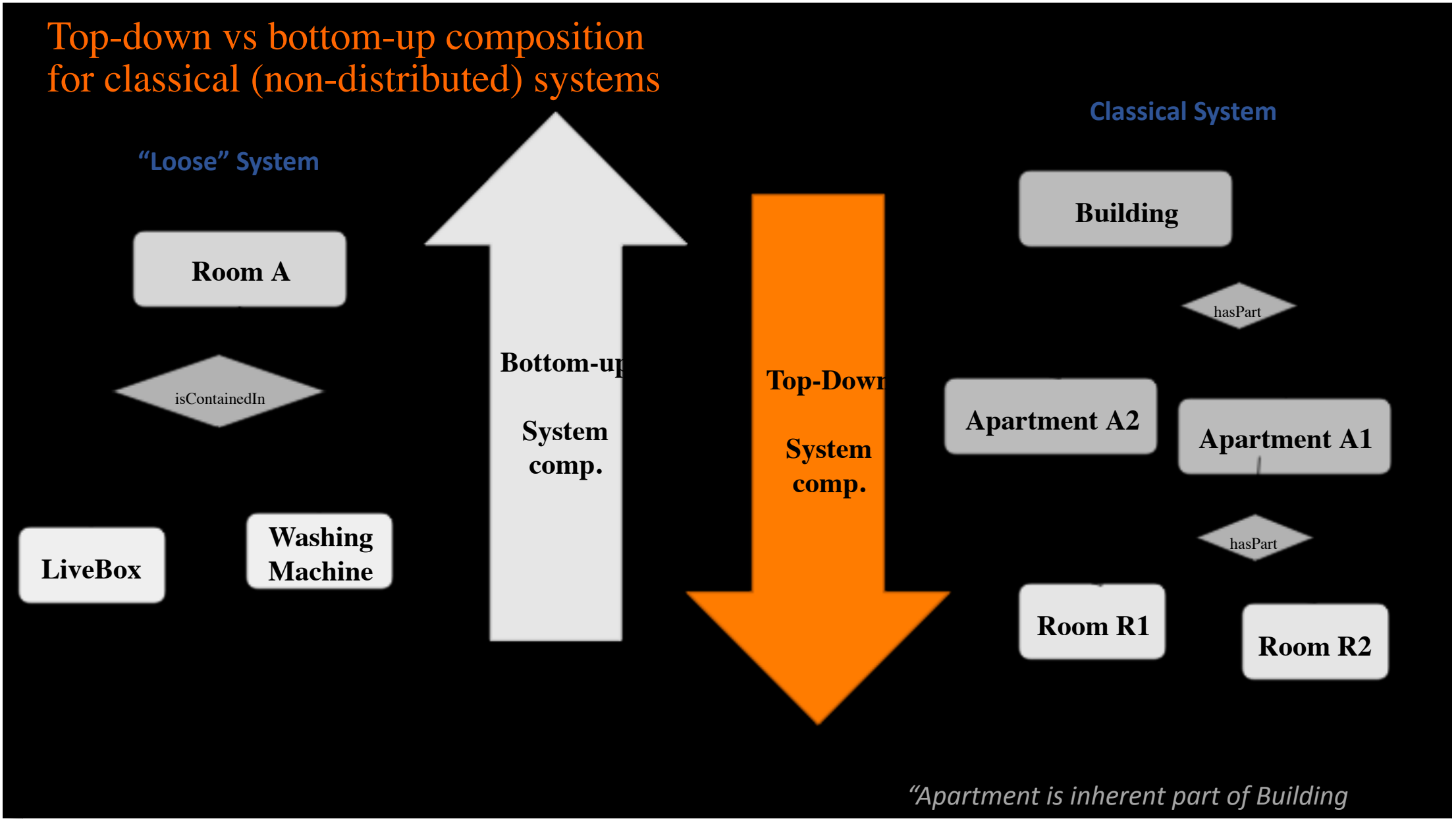
Thanks

Characterizing « systems of systems »

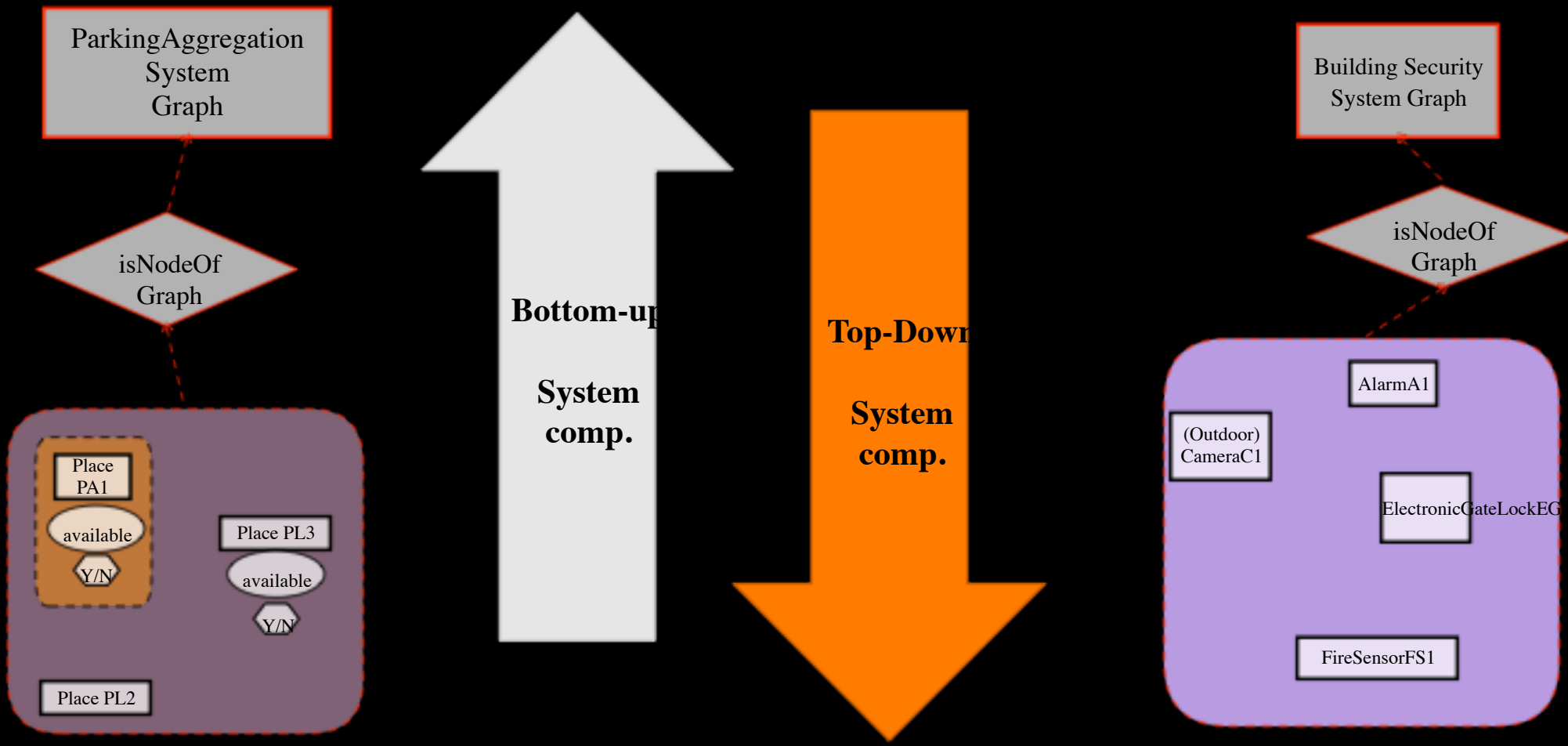
A system of systems is the aggregation of multiple subsystems which:

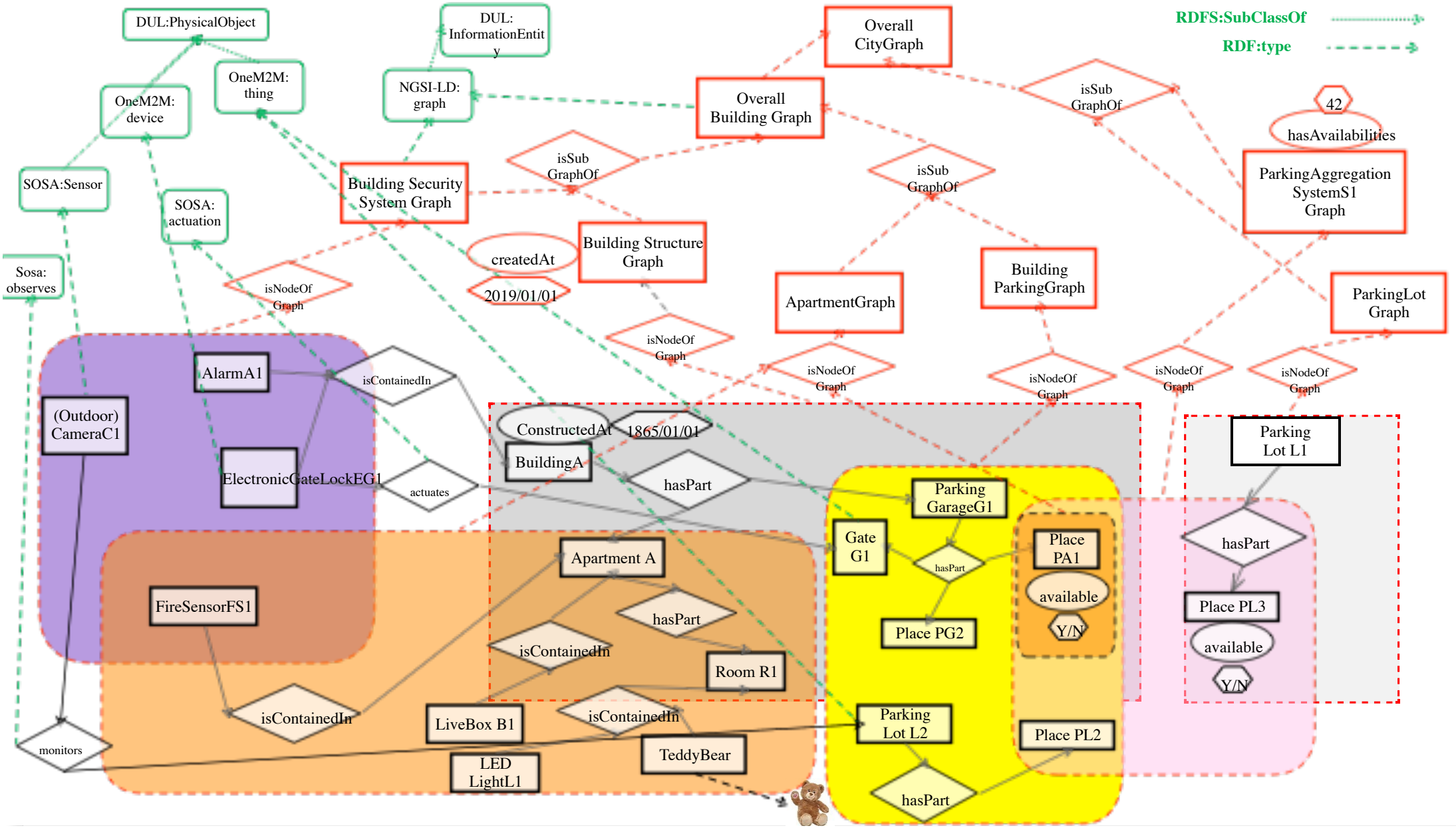


Top-down vs bottom-up composition for classical (non-distributed) systems



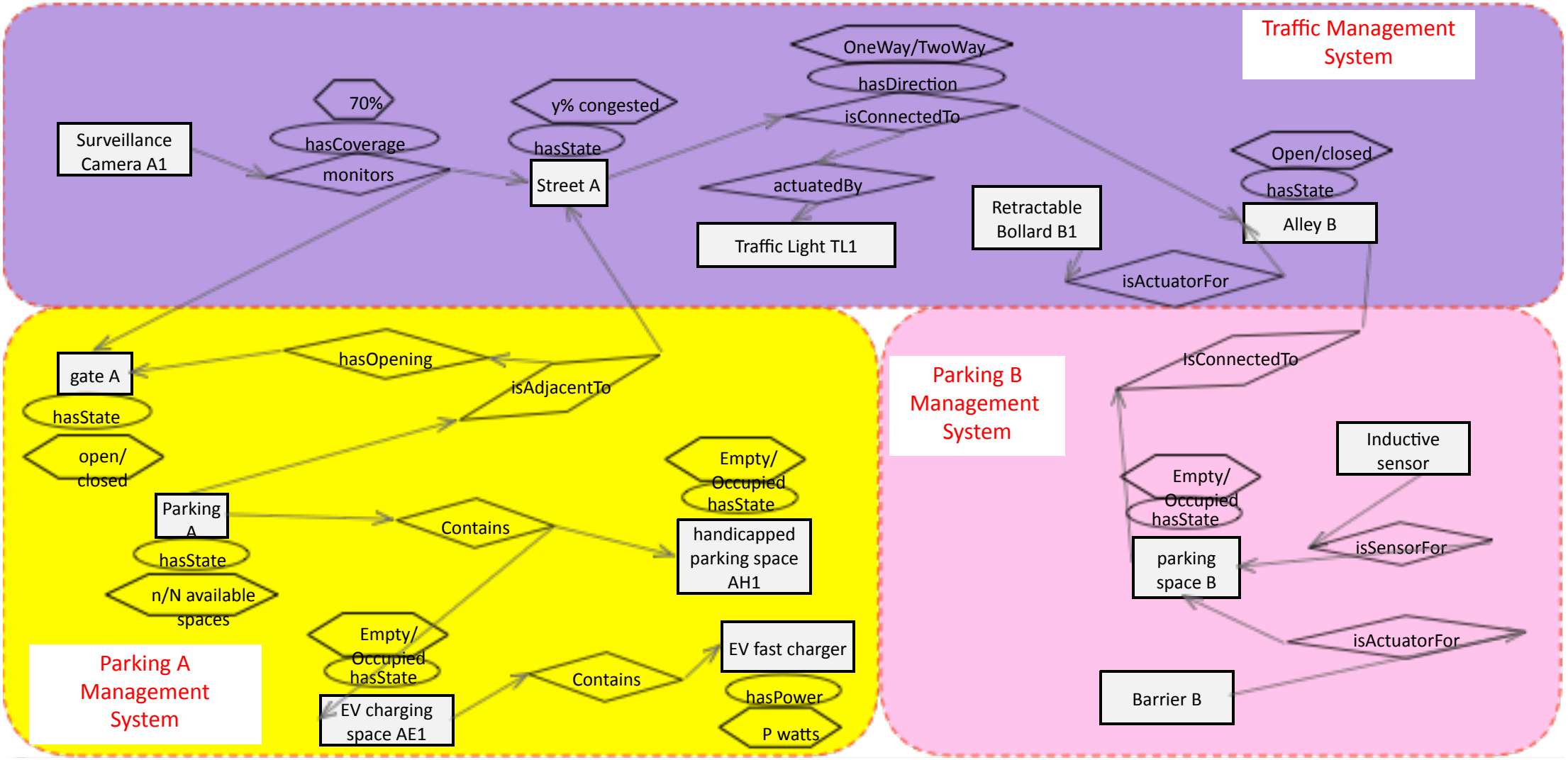
Top-down vs bottom-up composition for (distributed) systems of systems

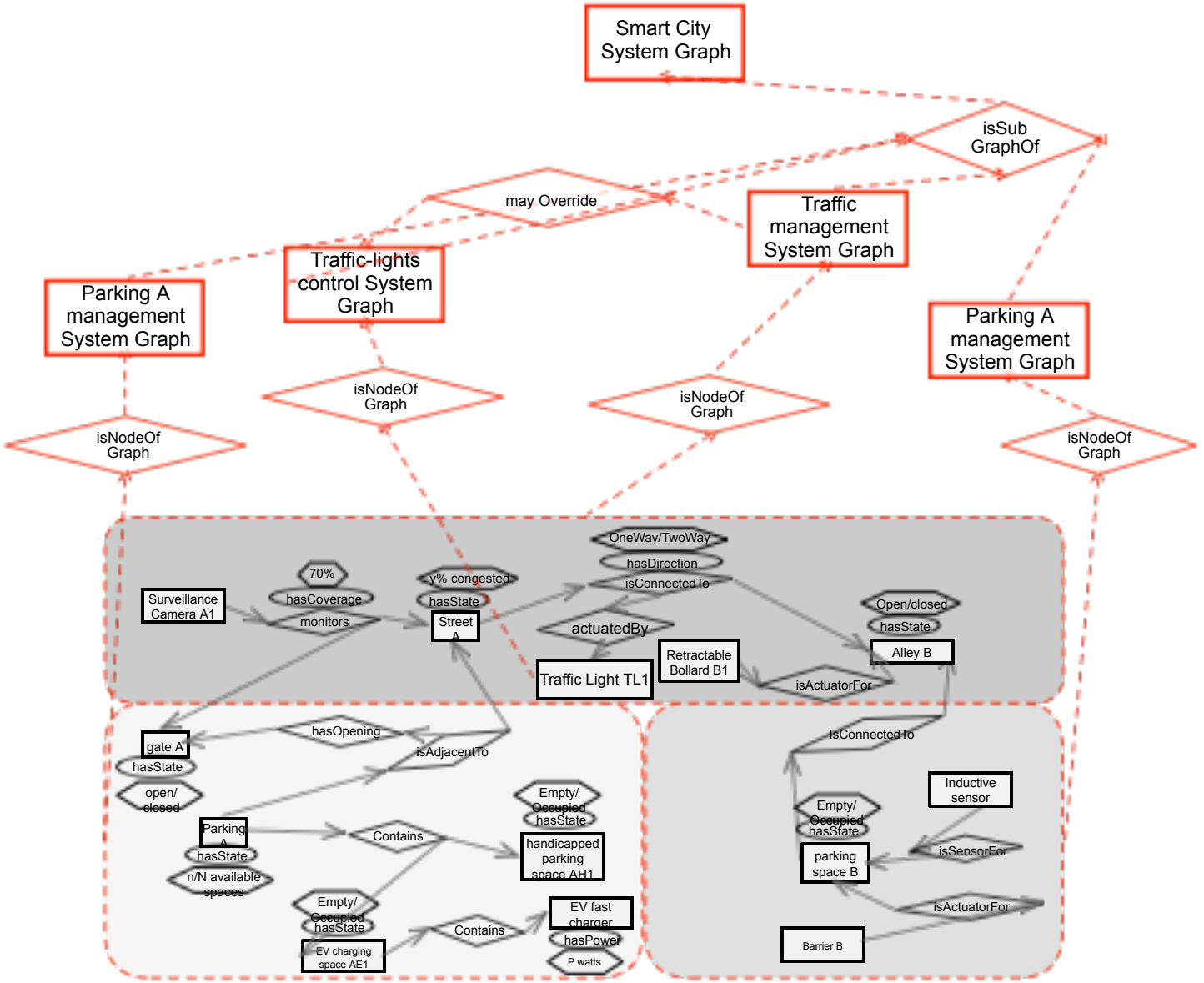



RDFS:SubClassOf
RDF:type
DUL:PhysicalObject
DUL: InformationEntity
Overall CityGraph
OneM2M: device
OneM2M: thing
NGSI-LD: graph
Overall Building Graph
isSub GraphOf
42
hasAvailabilities
SOSA:Sensor
SOSA: actuation
Building Security System Graph
isSub GraphOf
isSub GraphOf
ParkingAggregation SystemS1 Graph
Sosa: observes
createdAt
2019/01/01
Building Structure Graph
isNodeOf Graph
ApartmentGraph
Building ParkingGraph
ParkingLot Graph
AlarmA1
isContainedIn
(Outdoor) CameraC1
ElectronicGateLockEG1
actuates
ConstructedAt
1865/01/01
BuildingA
hasPart
Parking GarageG1
Parking Lot L1
Gate G1
hasPart
Place PA1
available
Y/N
Apartment A
hasPart
Place PG2
hasPart
Place PL3
available
Y/N
FireSensorFS1
isContainedIn
Room R1
isContainedIn
LiveBox B1
isContainedIn
Parking Lot L2
Place PL2
monitors
LED LightL1
TeddyBear
hasPart

Complementary Example :

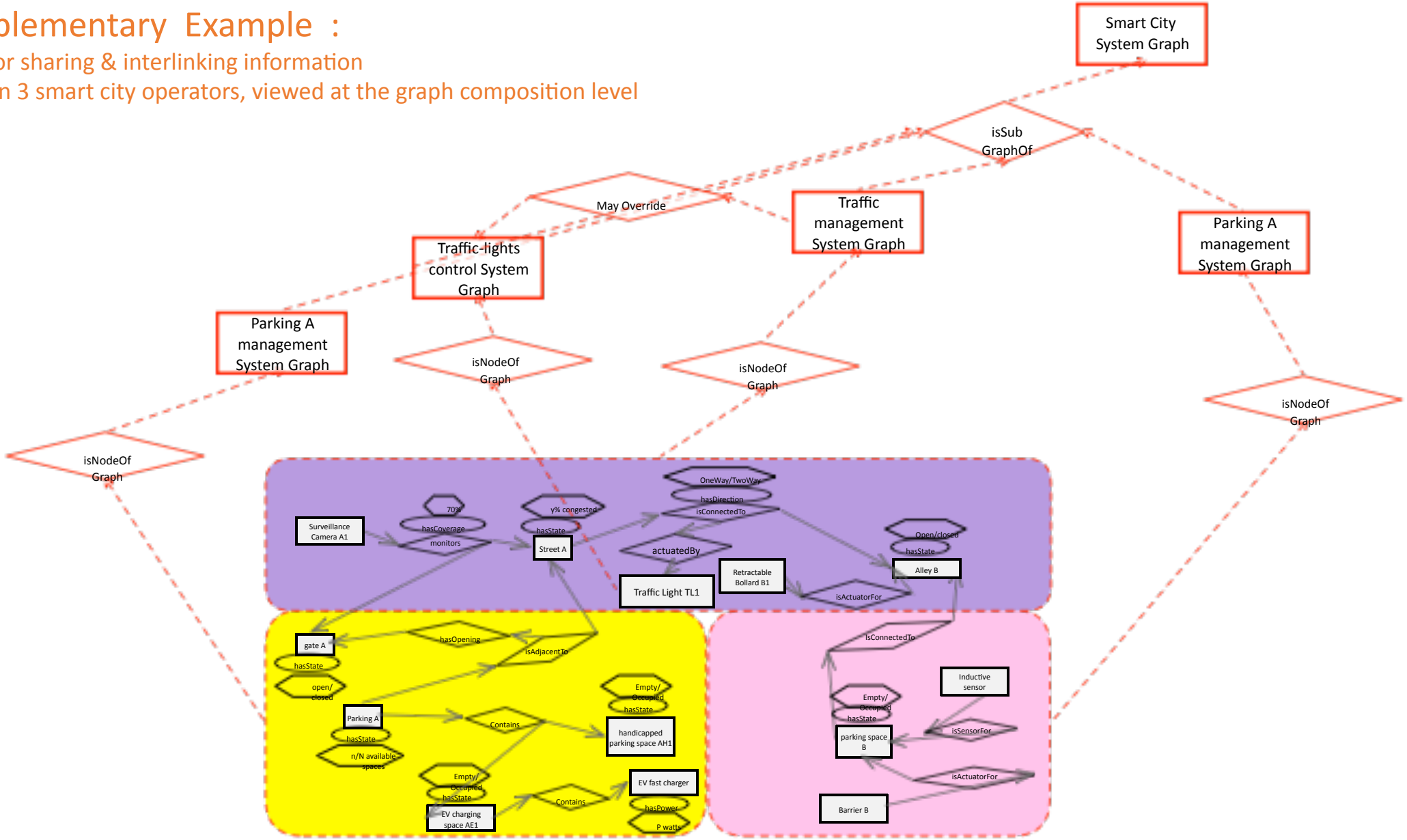
graph for sharing & interlinking information
between 3 smart city operators →flattened view



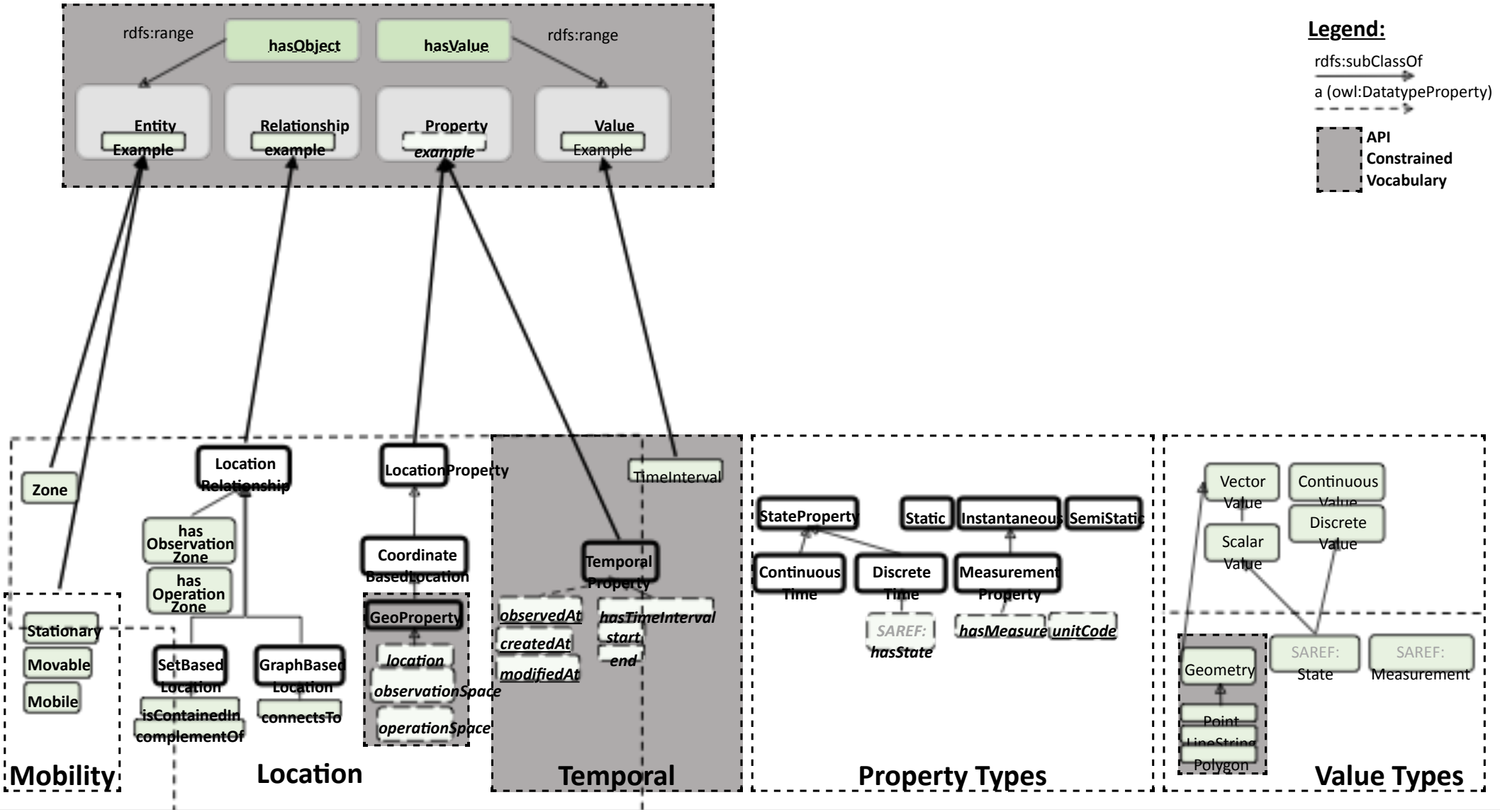
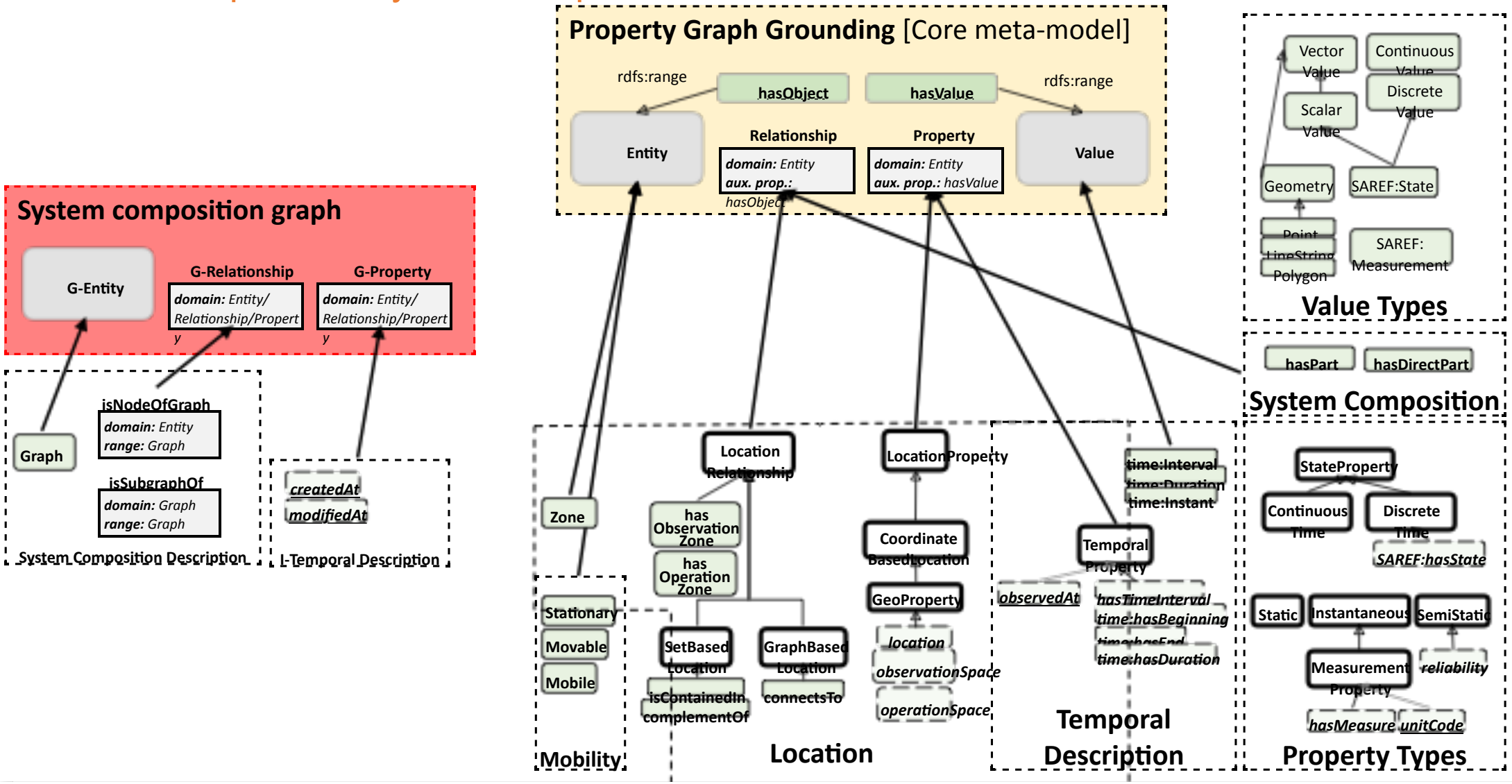

Smart City System Graph
isSub GraphOf
may Override
Traffic management System Graph
Traffic-lights control System Graph
Parking A management System Graph
Parking A management System Graph
isNodeOf Graph
isNodeOf Graph
isNodeOf Graph
isNodeOf Graph
OneWay/TwoWay
hasDirection
isConnectedTo
70%
hasCoverage
monitors
Surveillance Camera A1
y% congested
hasState
Street A
actuatedBy
Traffic Light TL1
Retractable Bollard B1
isActuatorFor
Open/closed
hasState
Alley B
hasOpening
isAdjacentTo
gate A
hasState
open/ closed
Parking A
hasState
n/N available spaces
Contains
Empty/ Occupied hasState
handicapped parking space AH1
Empty/ Occupied hasState
EV charging space AE1
Contains
EV fast charger
hasPower
P watts
IsConnectedTo
Inductive sensor
Empty/ Occupied hasState
isSensorFor
parking space B
isActuatorFor
Barrier B

Complementary Example :

graph for sharing & interlinking information
between 3 smart city operators, viewed at the graph composition level



Core ETSI CIM NGSI-LD Information model



Extensions of ETSI CIM NGSI-LD Information model for description of System composition