ONE-ITS2.0: Automating Multi-Stakeholder ITS Cyber-Physical Service Integration in the Internet of Everything Context

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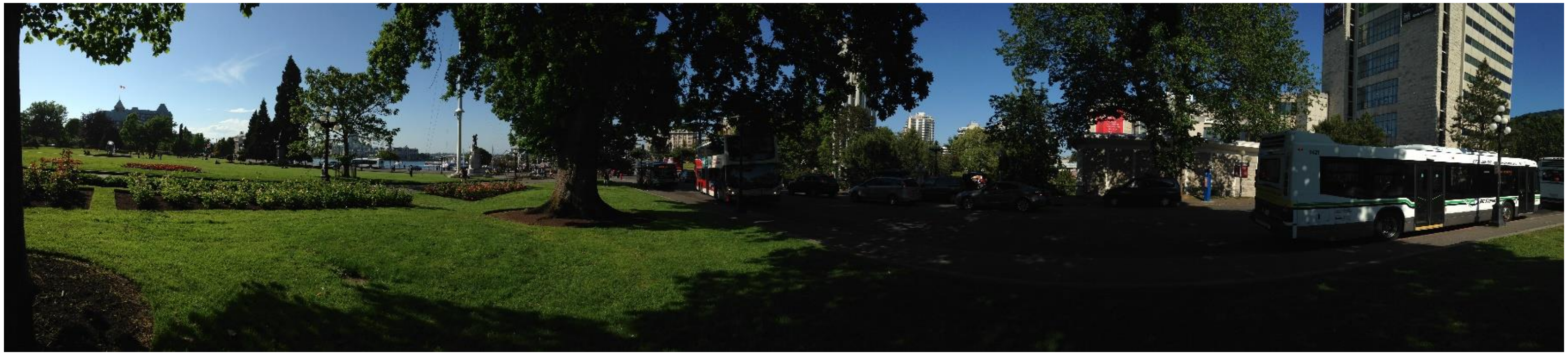
Outline

- Background and Motivation
- A Three-Pillar Framework to Support Seamless Coordination of Cyber-Physical ITS
  - Integrated Service Execution (ISE)
  - Integrated Service Planning (ISP)
  - Ontological Semantic Knowledge Representation (OSKR)
- A Proof-of-Concept ATIS Prototype
- Conclusions

Research Objectives
Intelligent Transportation System of Systems (ITSoS)

- To avoid the need to design, implement, and maintain large and complex regional **monolithic** systems.
  - Support greater connectivity and convergence of existing ITS sensors, services, and applications in the context of Internet of Things (IoT). **(Semantic interoperability)**
  - Facilitates collaboration and coordination across transportation stakeholders to design regional ITS plans. **(Coordinated Planning)**
  - Facilitates dynamic execution of ITS Plans to achieve stakeholders' common objectives. **(Automatic Integration)**

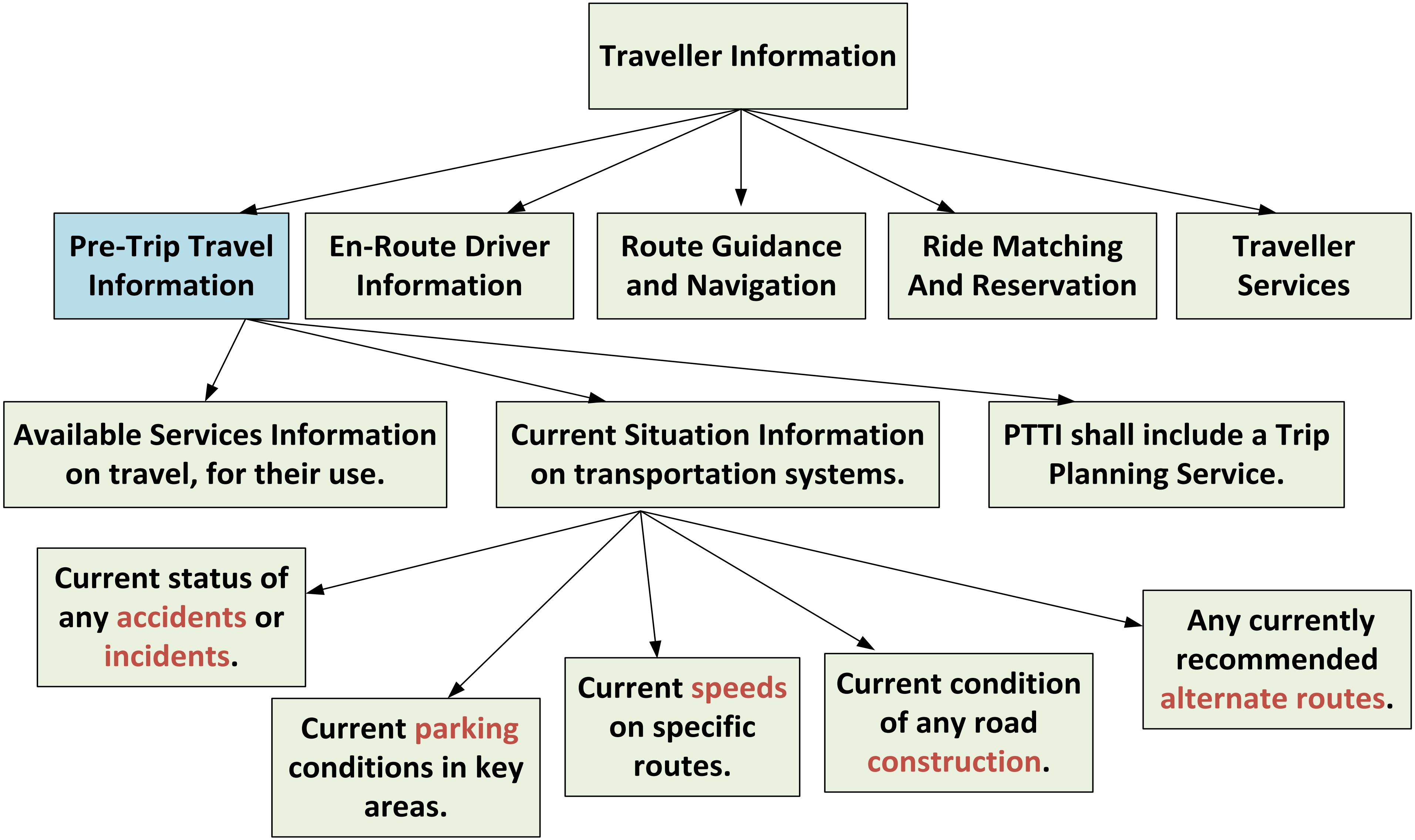
Monolithic systems vs SoS



Key SoS Characteristics (Maier, 1998)

- *Operational Independence* of the SoS elements
- *Managerial Independence* of the SoS elements
- *Evolutionary Development*
- *Emergent Behavior*
- *Geographic Distribution*

Motivational Example



A Three-Pillar Framework to Support Seamless Coordination of Cyber-Physical ITS

1

Ontological Semantic Knowledge Representation (OSKR)

- Ontology for Abstract ITS Operations (OITSP)
- Web Services (OWL-S)
- Sensors (SSN)
- Infrastructure (OTN)

2

Integrated Service Planning (ISP)

- Needs and Scope
- Functional Requirements
- Terminators
- Interfaces
- Hierarchical Tasks

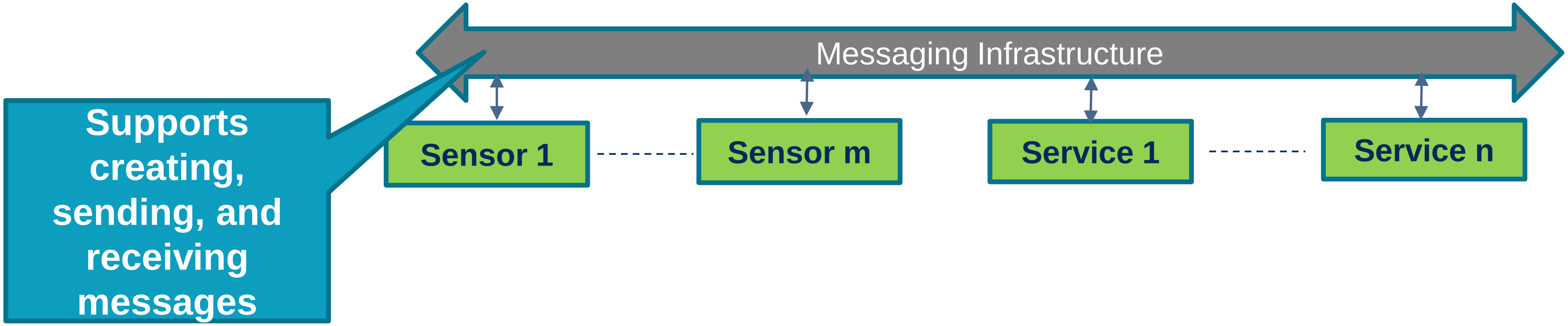
3

Integrated Service Execution (ISE)

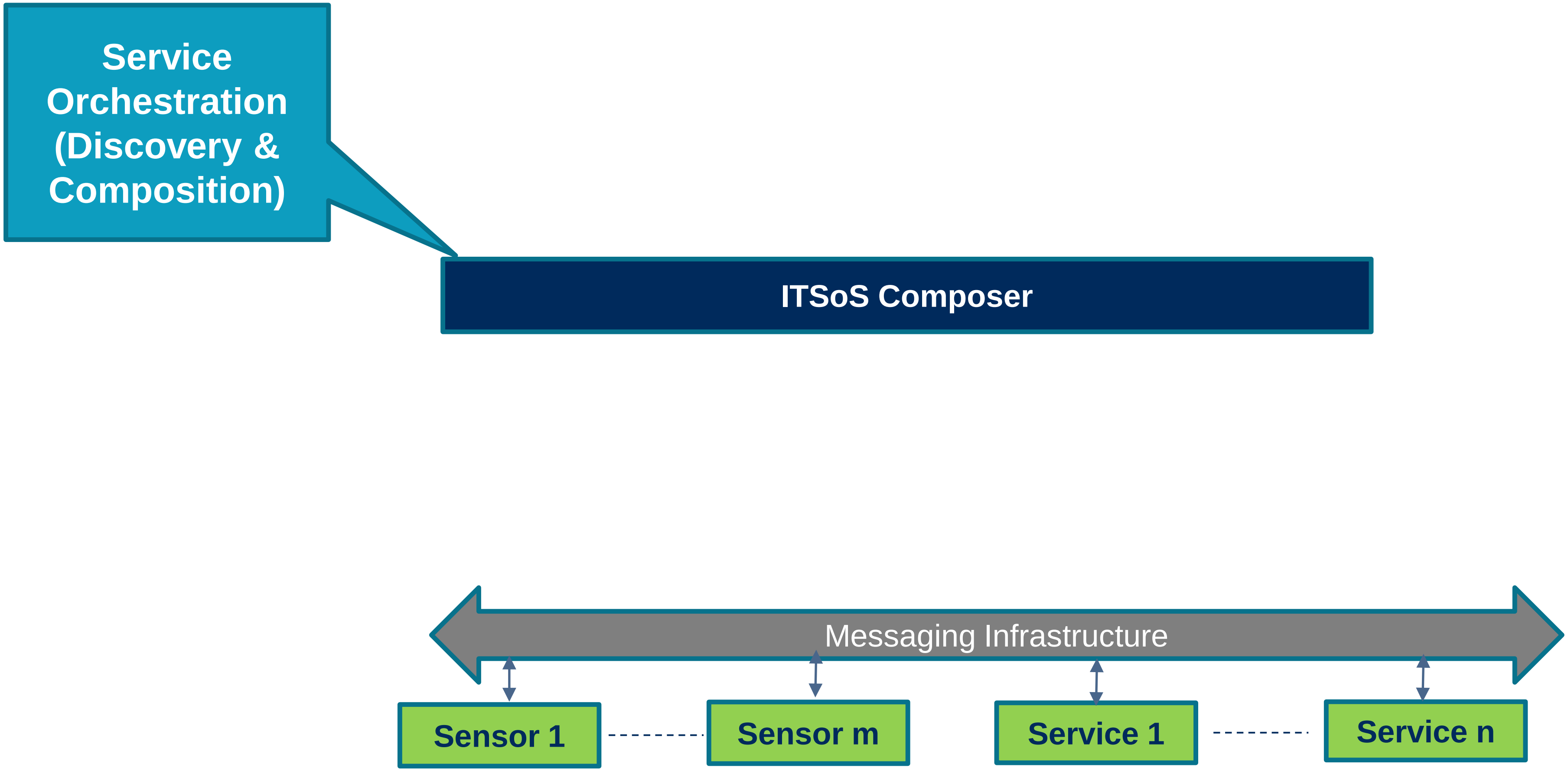
- ITSoS Composer
- Service Discovery
- Service Invocation
- Context Management
- ONE-ITS Portal

Integrated Service Execution (ISE)

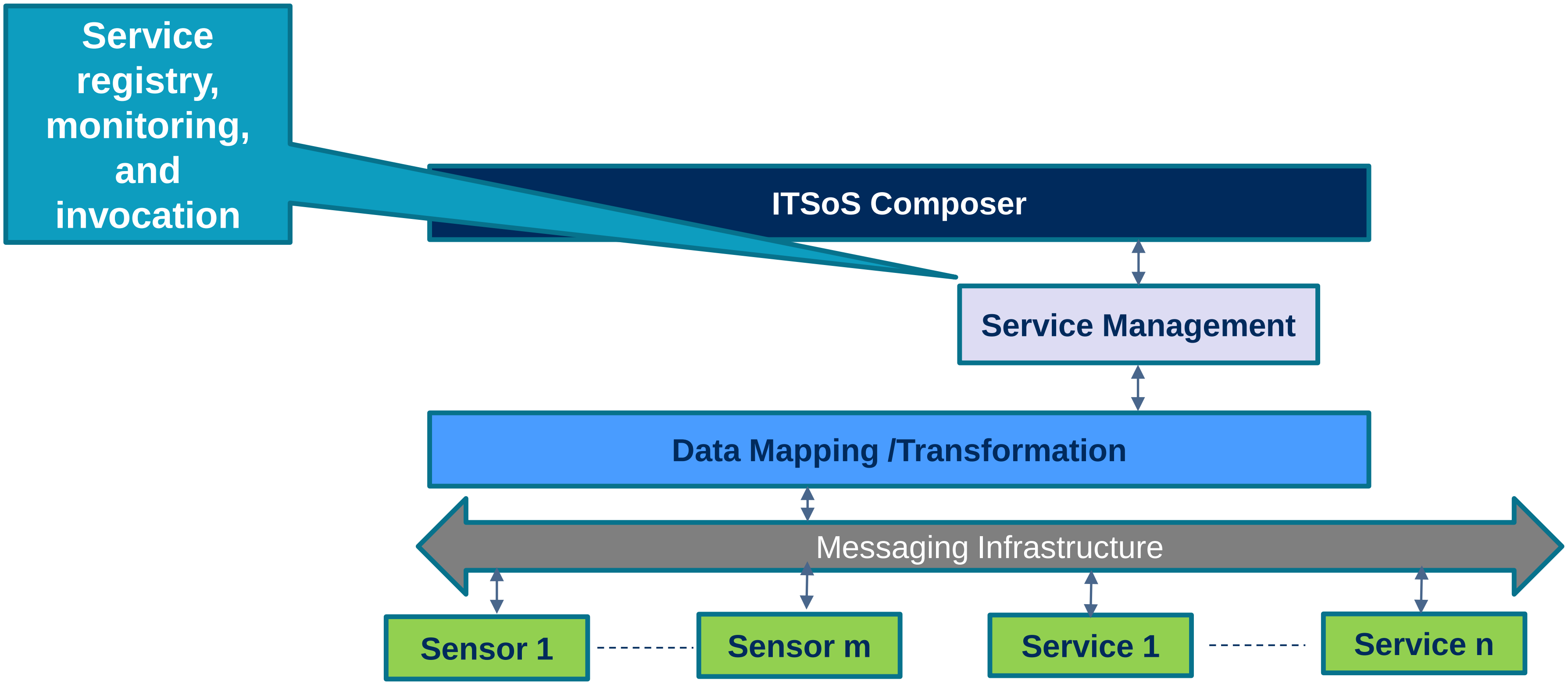
Integrated Service Execution (ISE)



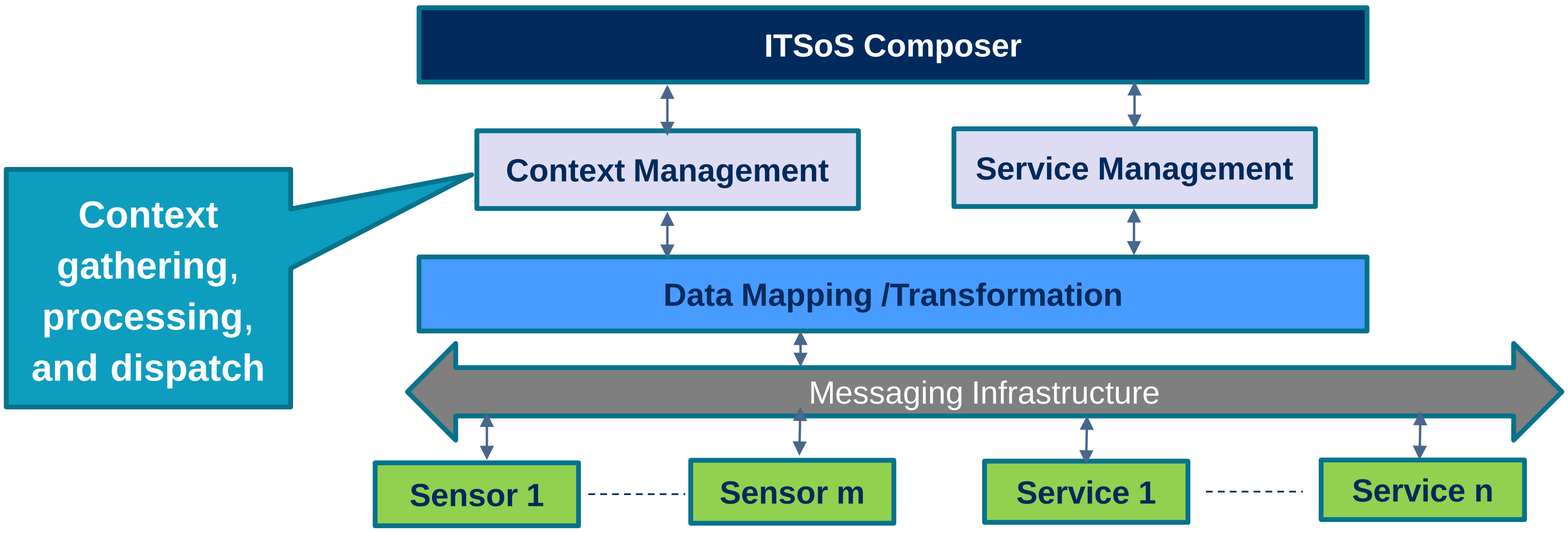
Integrated Service Execution (ISE)



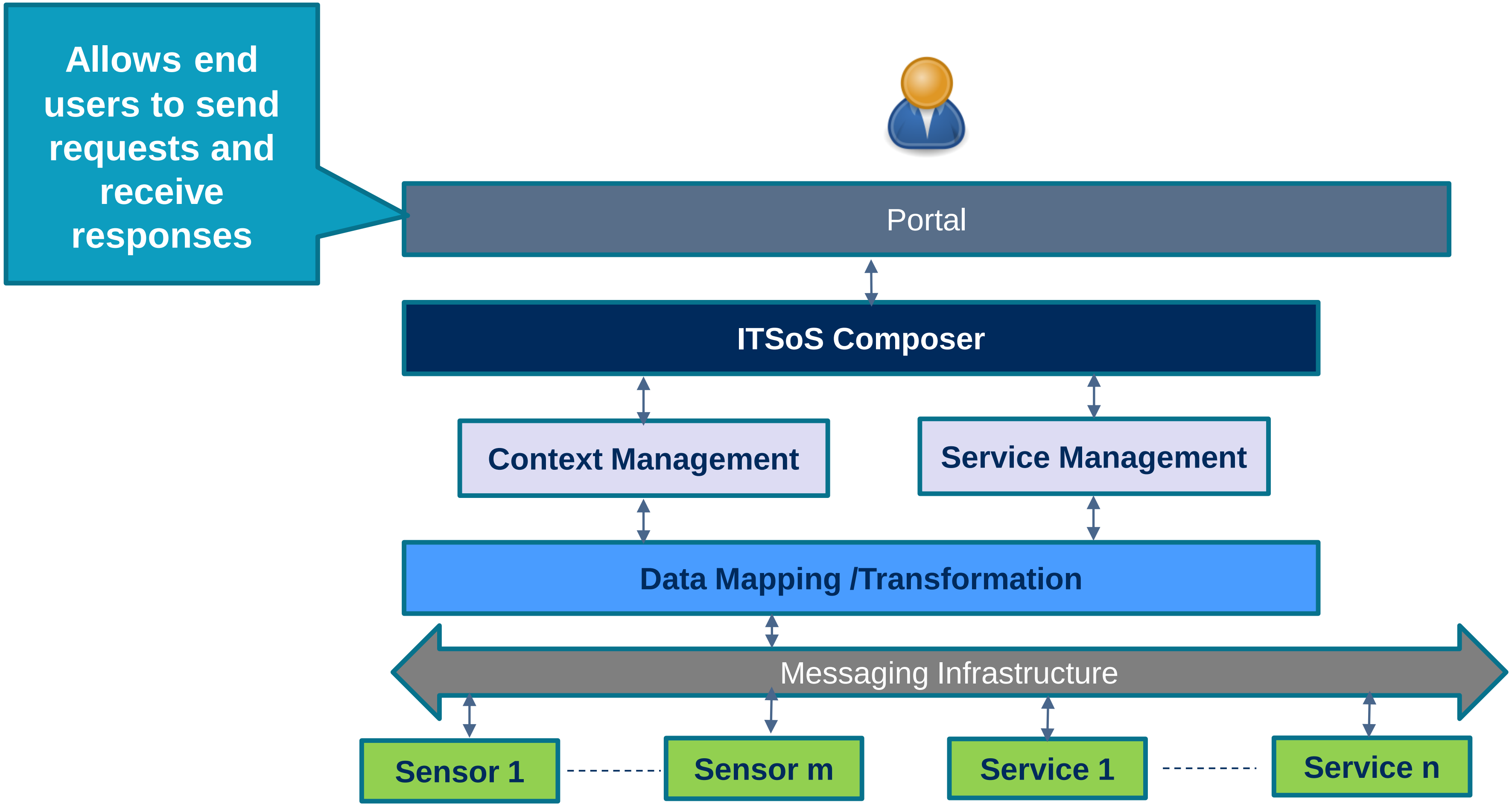
Integrated Service Execution (ISE)



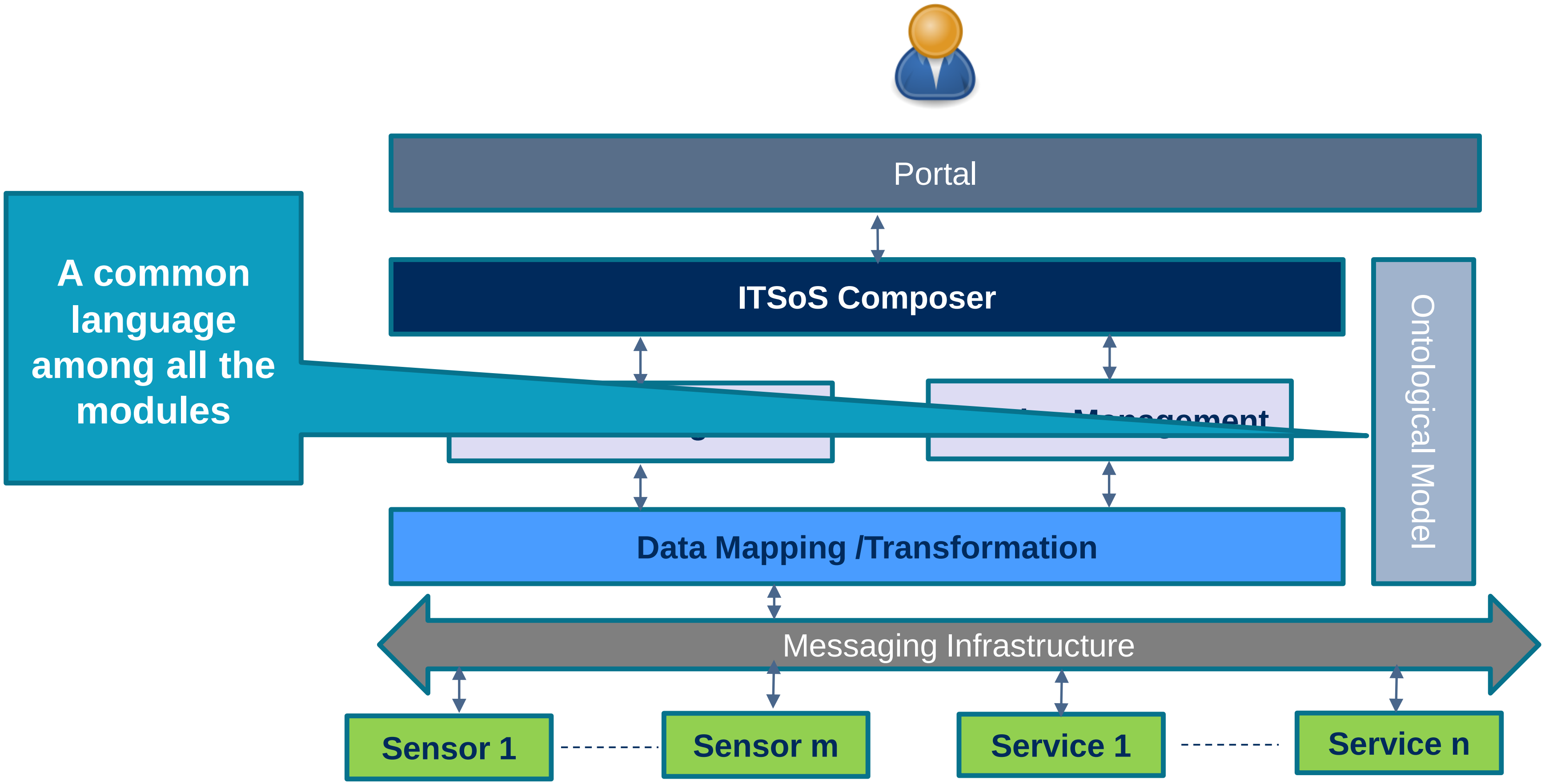
Integrated Service Execution (ISE)



Integrated Service Execution (ISE)



Integrated Service Execution (ISE)



Integrated Service Planning (ISP)

1) Identify Needs and Scope

2) Determine Key Services and Functional Requirements

3) Define Terminators and Interfaces

4) Develop an Operational Procedure (Task Network Definition)

Integrated Service Planning (ISP)

Concerned Stakeholders
Overall Goals
Geographic Boundaries
Timeframe

1) Identify Needs and Scope

2) Determine Key Services and Functional Requirements

3) Define Terminators and Interfaces

4) Develop an Operational Procedure (Task Network Definition)

Integrated Service Planning (ISP)

Select the standardised ITS User Services, Processes, Equipment Packages, and Functional Requirements

1) Identify Needs and Scope

2) Determine Key Services and Functional Requirements

3) Define Terminators and Interfaces

4) Develop an Operational Procedure (Task Network Definition)

Integrated Service Planning (ISP)

1) Identify Needs and Scope

2) Determine Key Services and Functional Requirements

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Defines the terminators interacting with the application and the interfaces Equipment Packages, communicating the messages among the consistent components of the ITSoS application

Integrated Service Planning (ISP)

1) Identify Needs and Scope

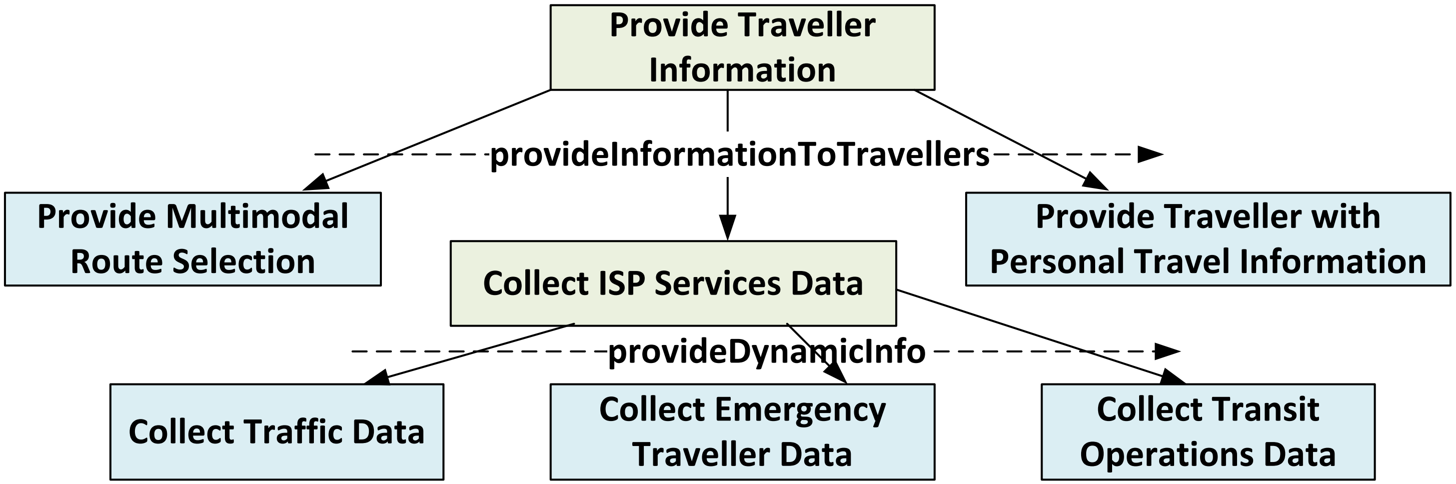
2) Determine Key Services and Functional Requirements

3) Define Terminators and Interfaces

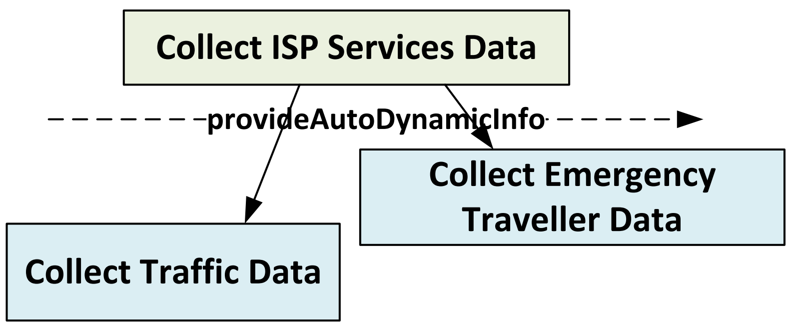
4) Develop an Operational Procedure (Task Network Definition)

Use the *Hierarchical Task Analysis (HTA)* to define tasks, subtasks, sequence of execution, and conditions for triggering the actions

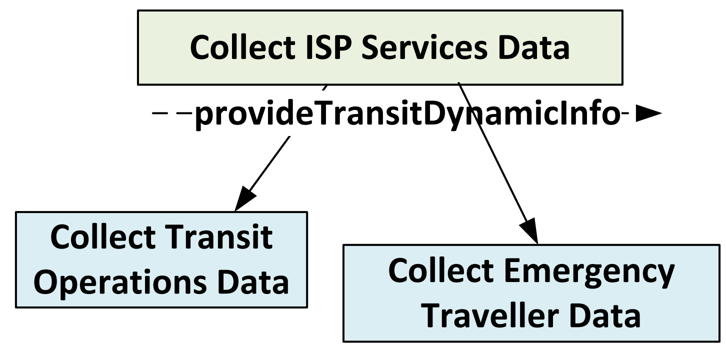
Example: Abstract ITS plan of an ATIS Operation



a) Multimodal Mode Decomposition

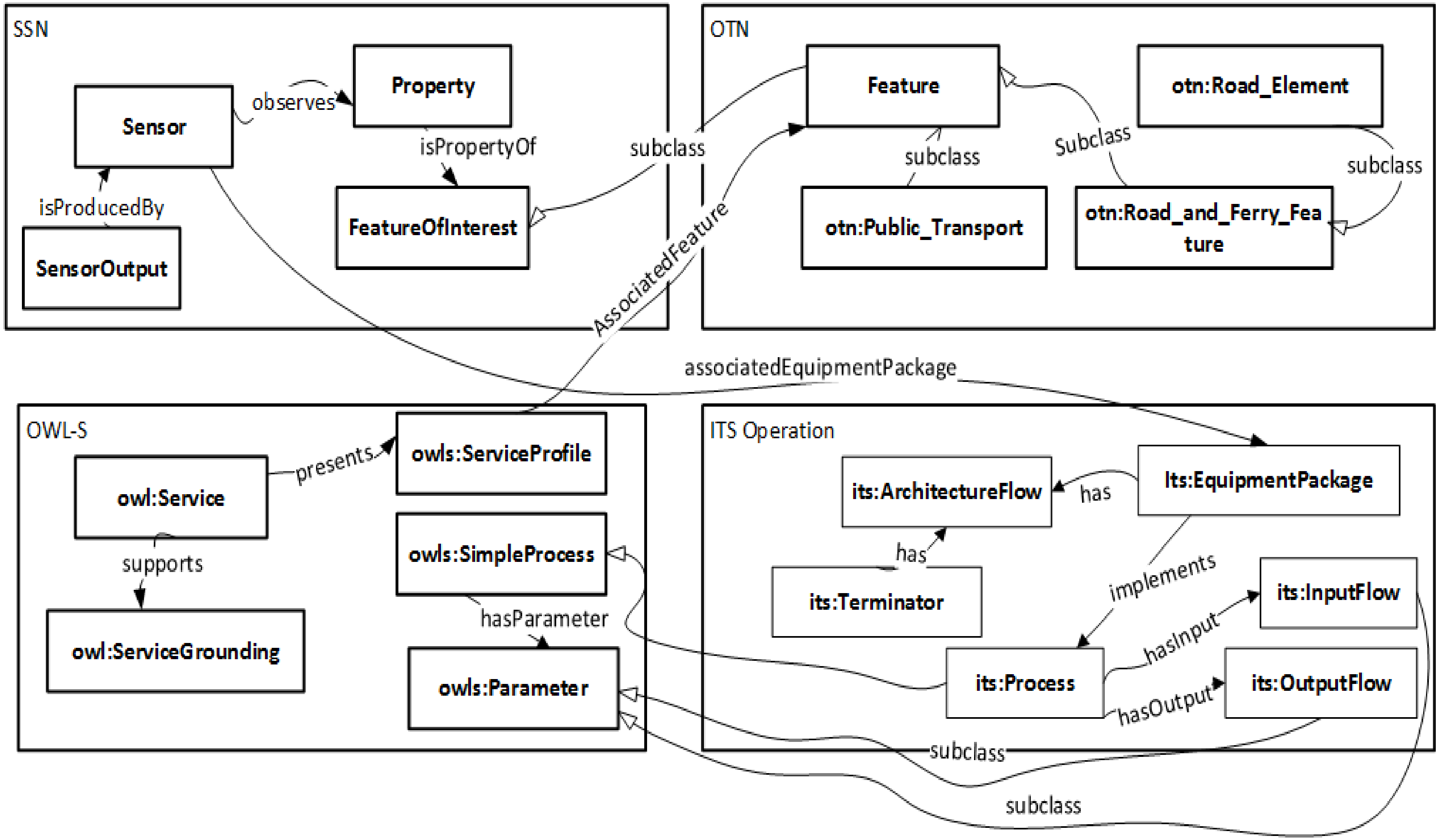


b) Real-time Mode Decomposition (Auto Mode)



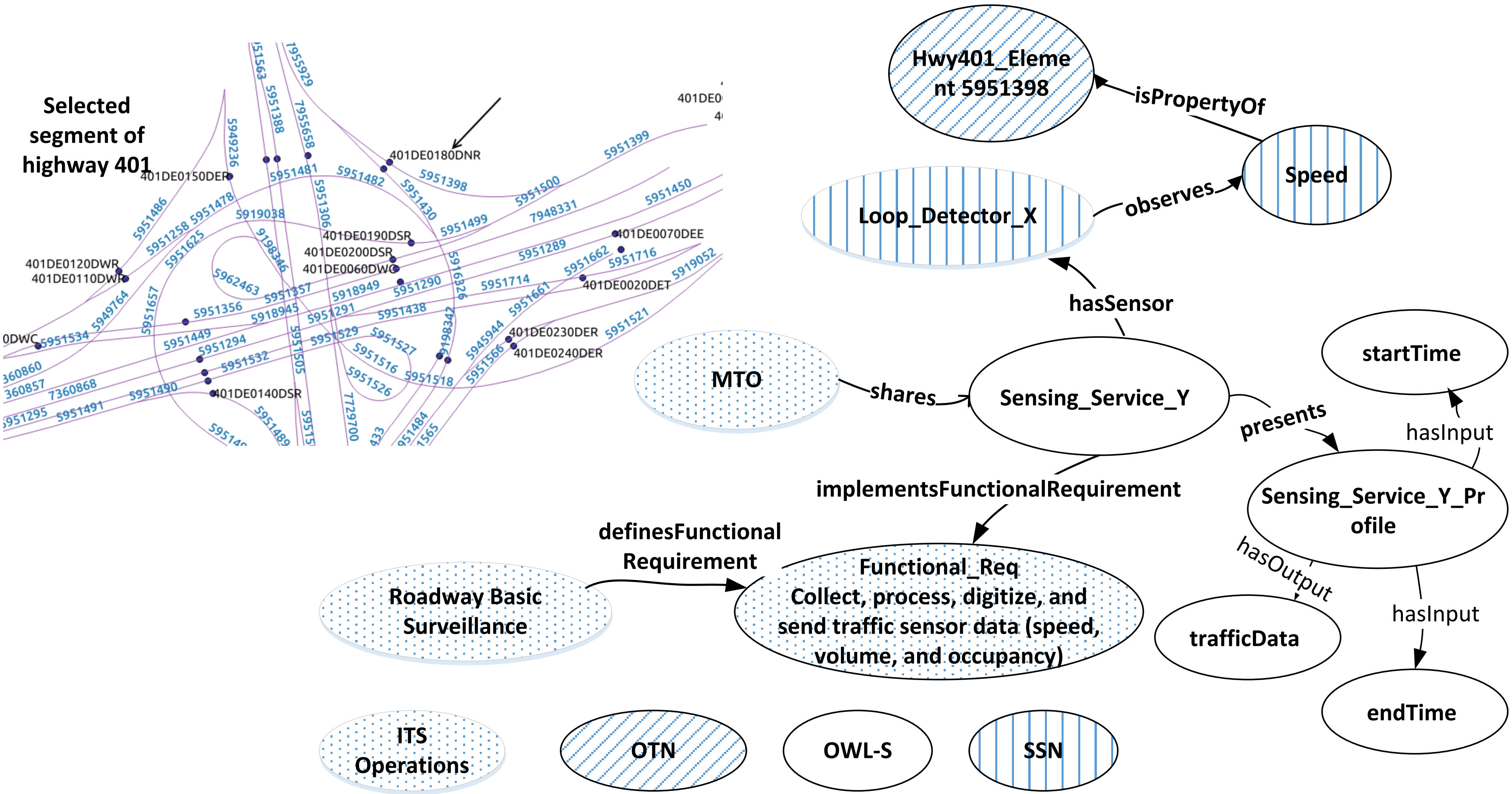
c) Real-time Mode Decomposition (Transit Mode)

Ontological Semantic Knowledge Representation (OSKR)



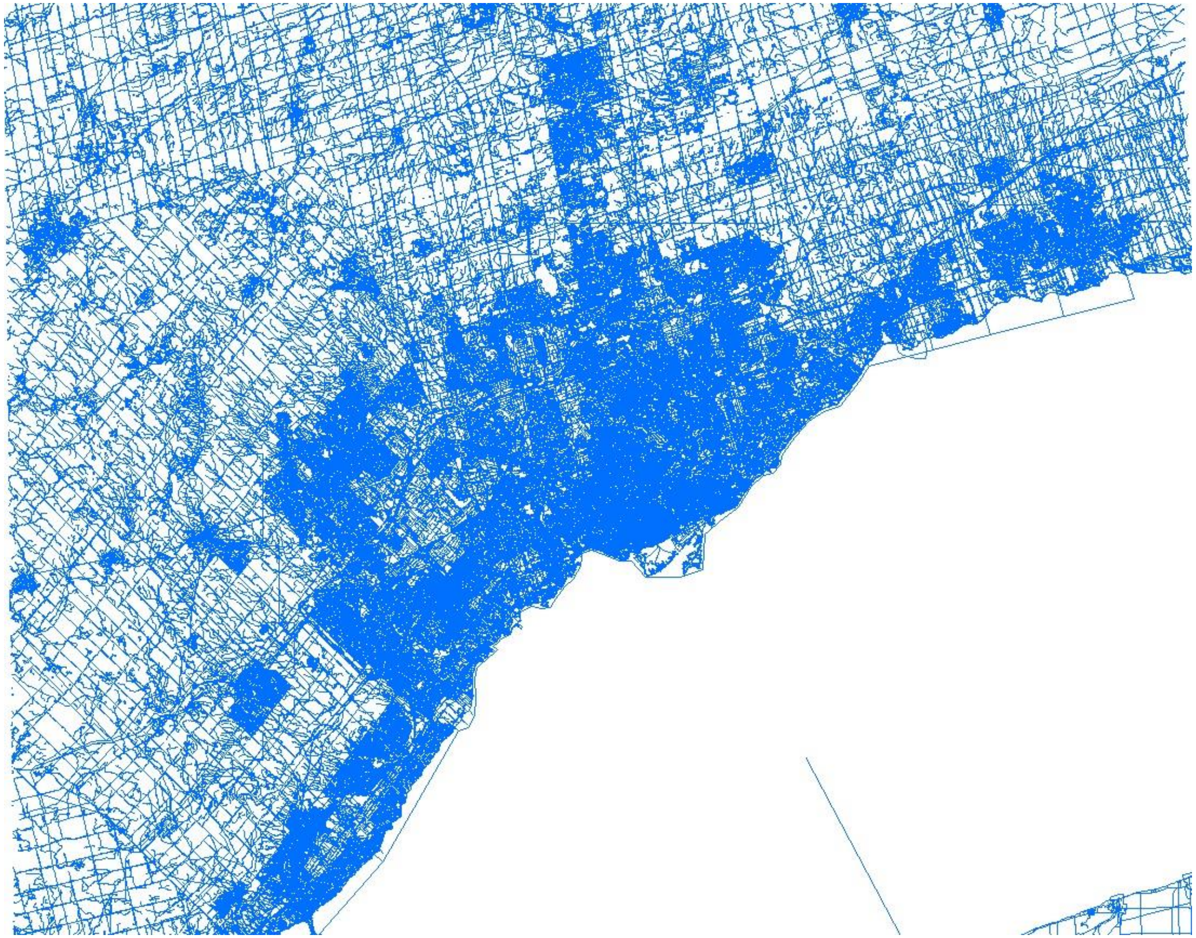
Example

Selected segment of highway 401



Proof-of-Concept ATIS Prototype

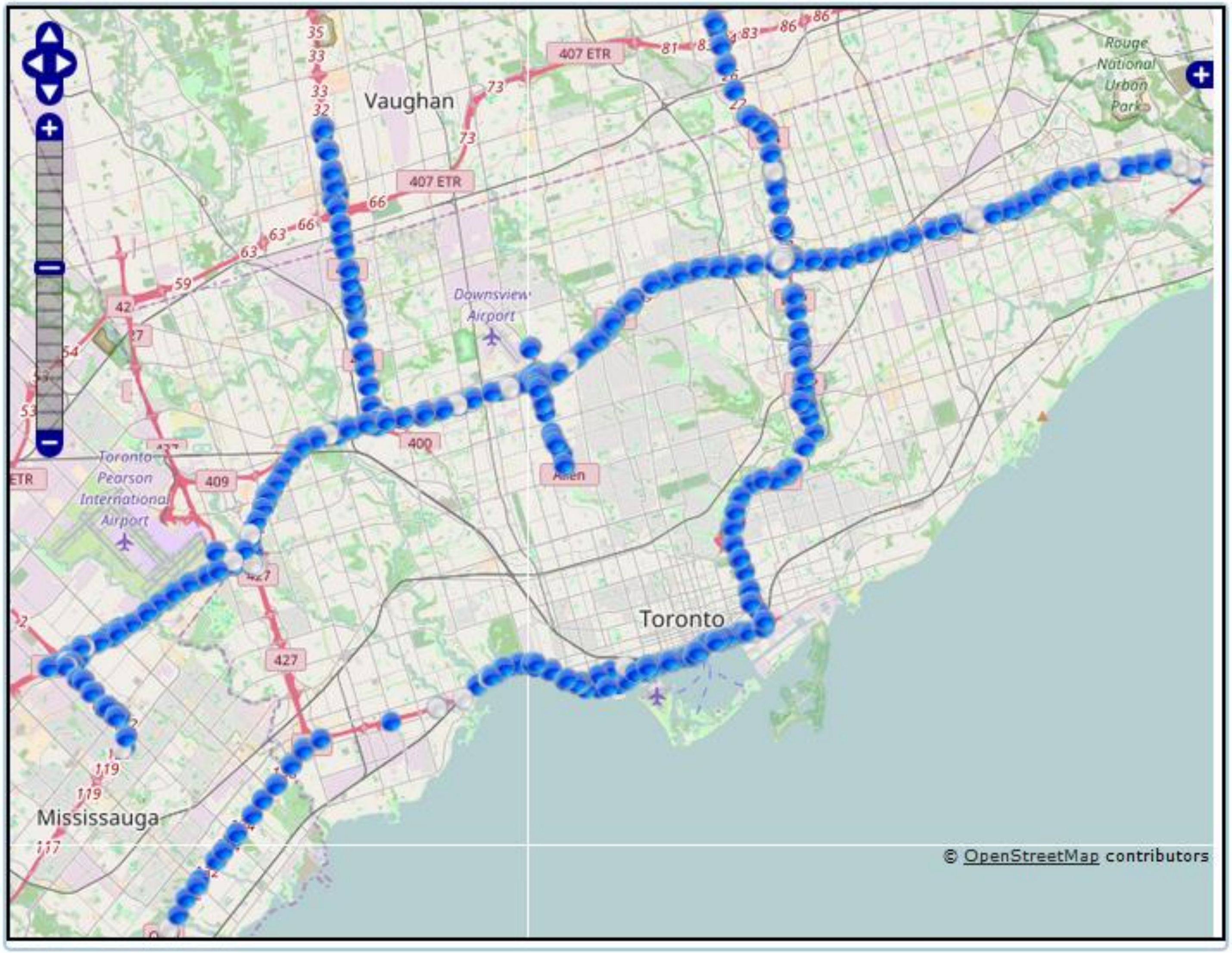
Open Street Maps



GTFS

TTC
GO
YRT
Brampton Transit
Oakville Transit
Durham Region Transit
Burlington Transit
MiWay

Sensors


Vaughan
407 ETR
Downsview Airport
Toronto Pearson International Airport
Rouge National Urban Park
Toronto
Mississauga
Allen
409
400
427
© OpenStreetMap contributors

Proof-of-Concept ATIS Prototype

Service	ITS Abstract Process
GTAPlannerService	Provide Multimodal Route Selection
IncidentListInqRq	Collect Emergency Traveller Data
GTATrafficService	Collect Traffic Data
NextBusMessagesService	Collect Transit Operations Data
GTAStopsService	Collect Transit Operations Data
NextBusPredictionsService	Collect Transit Operations Data

Proof-of-Concept ATIS Prototype

Origin = 43.77010, -79.39596

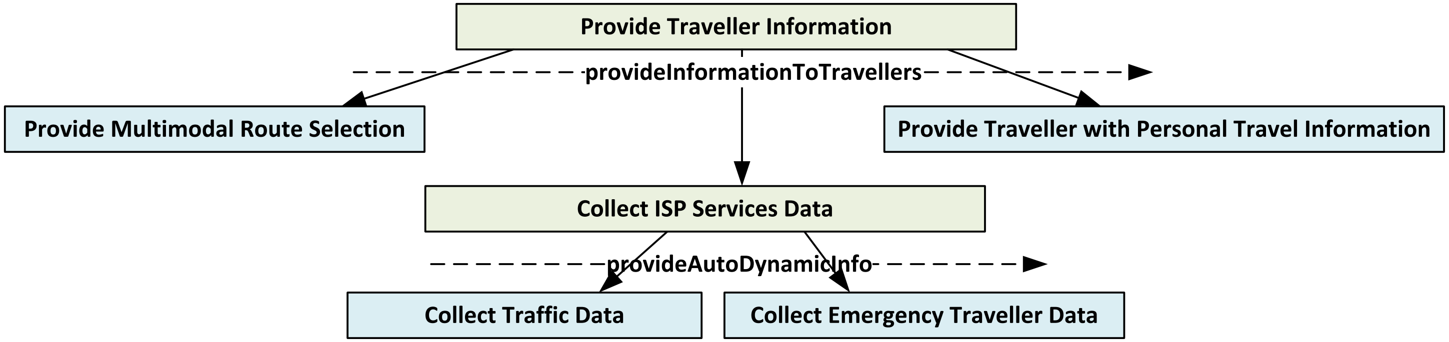
Destination = 43.65968, -79.43184

Modes = CAR

Services:

GTATrafficService

IncidentListInqRq



Proof-of-Concept ATIS Prototype

Origin =43.81967, -79.33022

Destination =43.65943, -79.38789

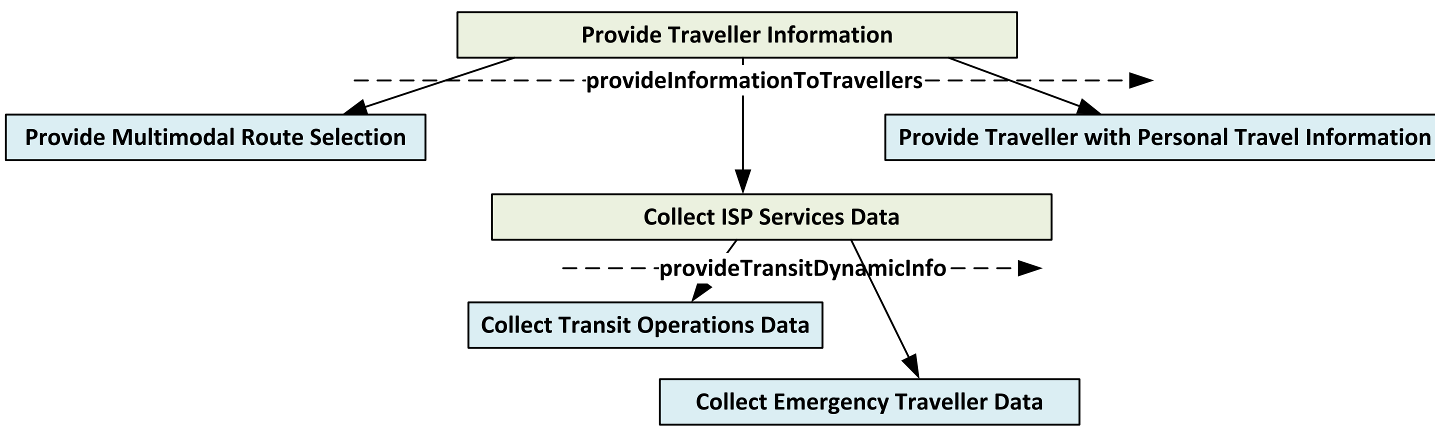
Modes = WALK, TRANSIT

Services:

NextBusMessagesService (for route 53, 1)

GTAStopsService (for stops 10138, 14111)

NextBusPredictionsService (for stops 10138, 14111)



Proof-of-Concept ATIS Prototype

Origin =43.80257, -79.39476

Destination =43.68674, -79.39991

Mode=CAR_PARK,WALK, TRANSIT

Services:

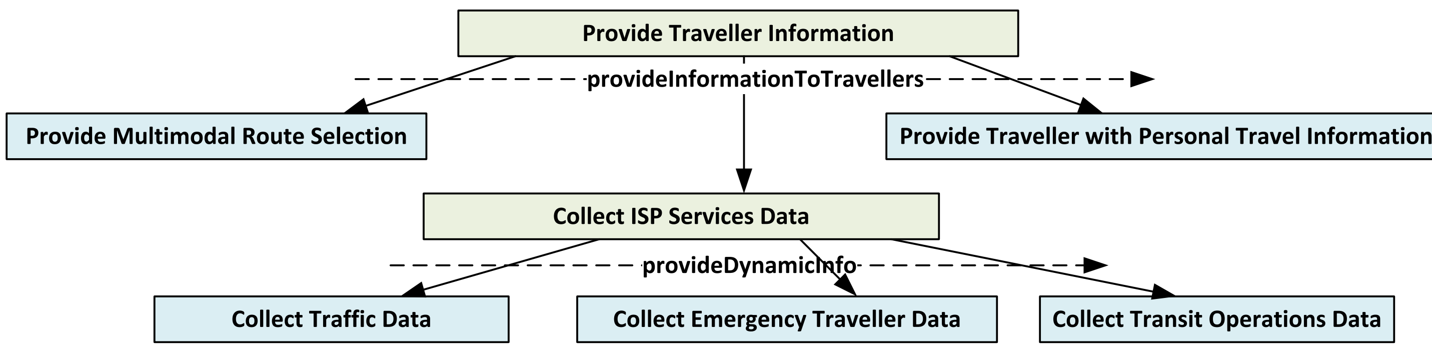
GTATrafficService

IncidentListInqRq

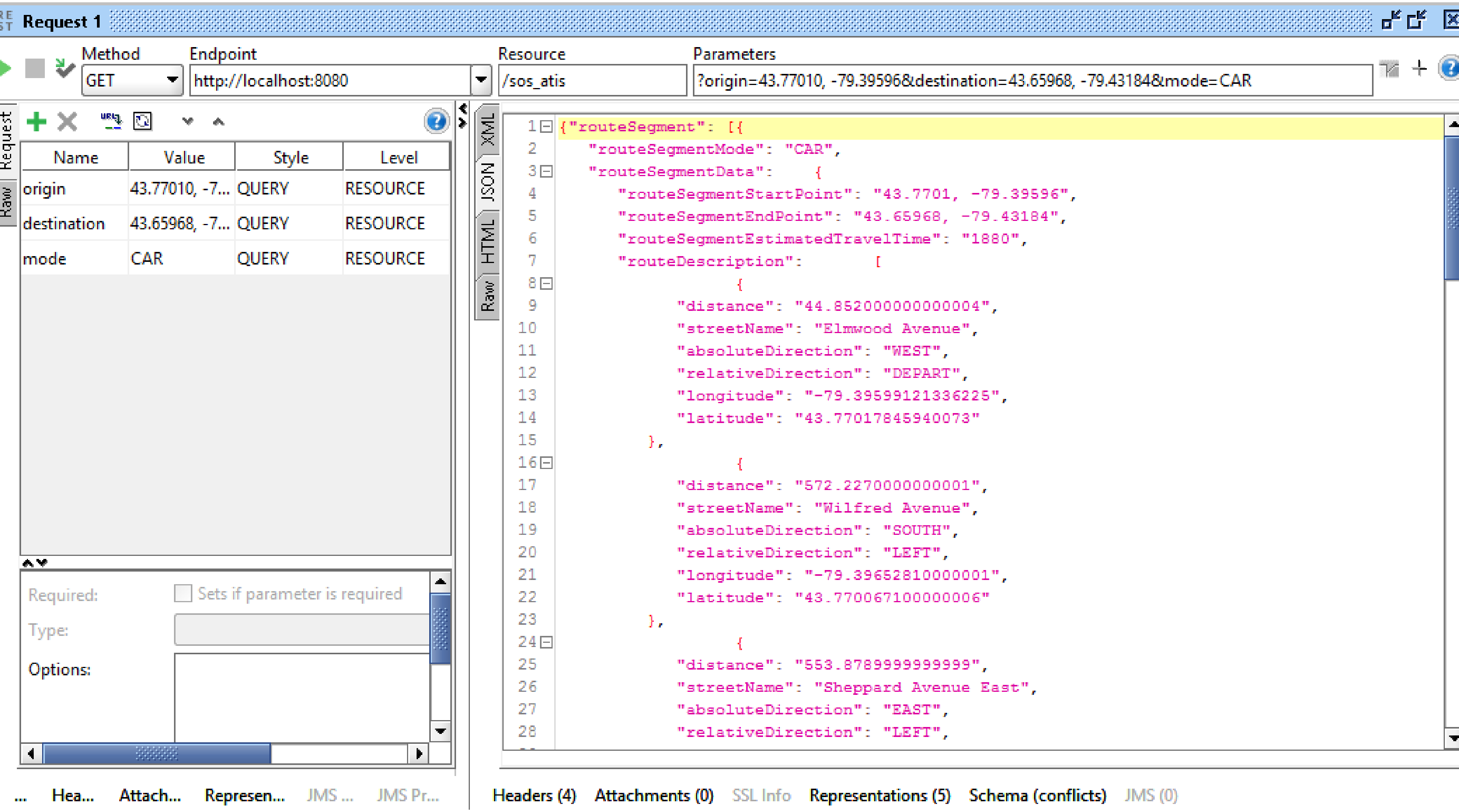
NextBusMessagesService (for route 1)

GTAStopsService (for stops 14111)

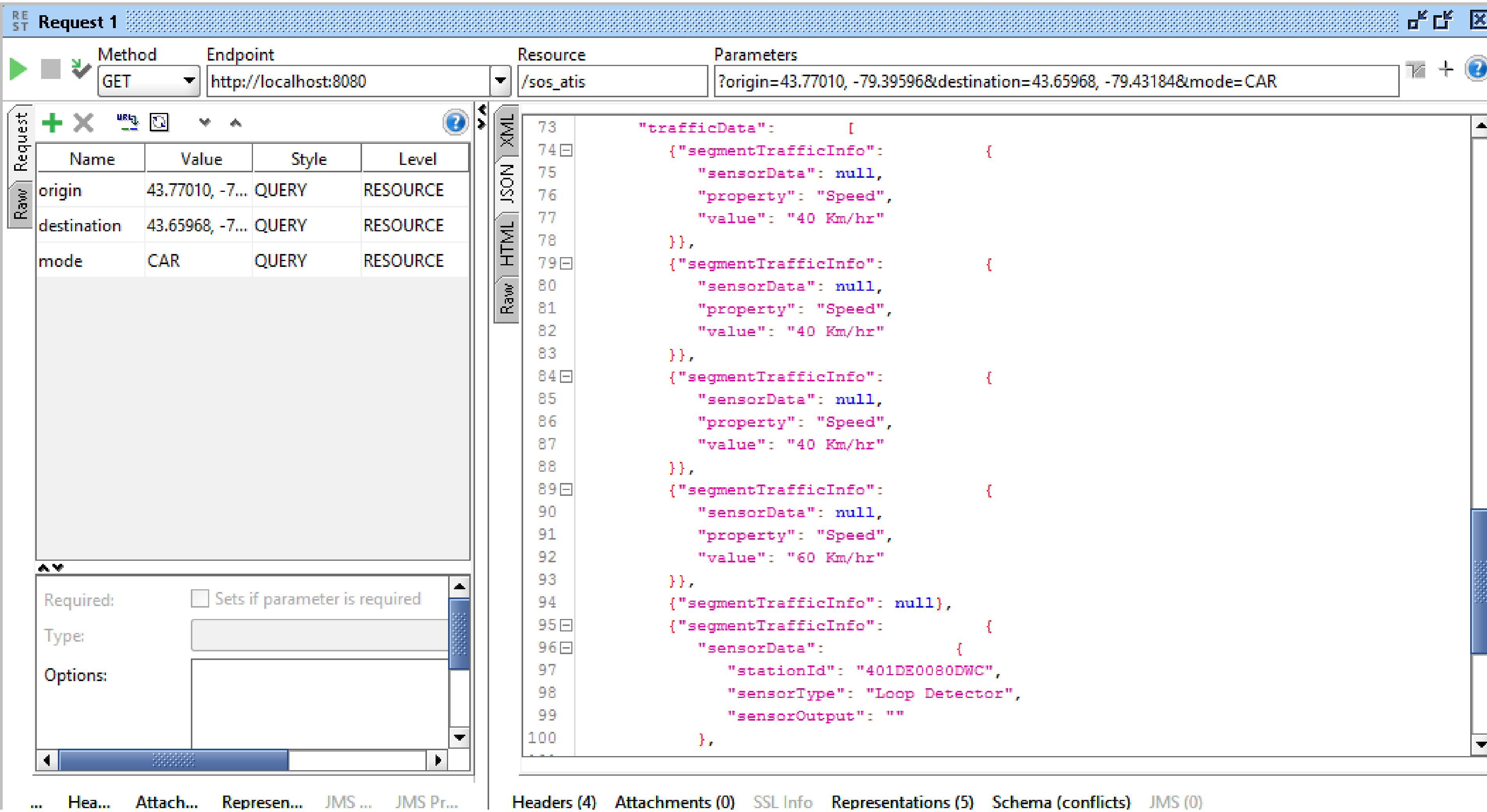
NextBusPredictionsService (for stops 14111)



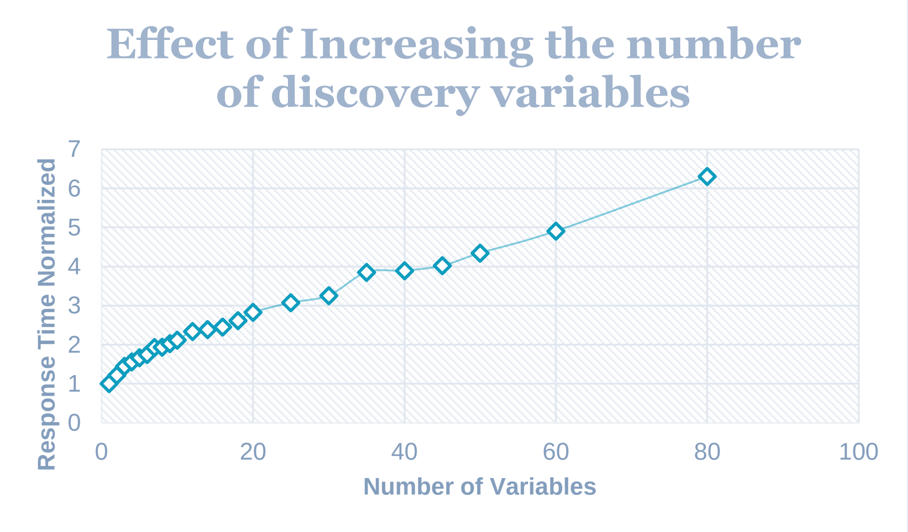
An Example Request



An Example Request (Cont.)



Computational Performance Evaluation of the ITSoS Composer



Initial Task	Plan Size	Normalized Response Time
Complete traveller information services	4770	80.64
Pre-trip travel information	1711	53.89
En-route driver information	495	32.72
Route guidance and navigation	959	57.43
Ride matching and reservation	709	47.52
Travel-related services and facilities	1370	50.58
Trip planning service	537	38.21
Provide information on current situational information on transportation systems	519	45.17
Collect Traffic Data	9	4.58
Collect Highway Traffic information	1	1

Conclusions

- The ITS standards provide a solution to the *syntactical* barriers of achieving interoperability within an ITSoS , however, they do not overcome the *semantic* interoperability barriers that hinder the ability of the ITSoS to dynamically compose its constituent components.

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- The ITS standards provide a solution to the *syntactical* barriers of achieving interoperability within an ITSoS , however, they do not overcome the *semantic* interoperability barriers that hinder the ability of the ITSoS to dynamically compose its constituent components.
- There is a *gap* between the *general* processes, as represented by the ITS architecture, and the *real* processes developed by the transportation jurisdictions and municipalities. Such gap precludes the ability to use the architecture in the planning of ITSoS applications.

Conclusions

- Enabling an ITSoS requires:
  - A common model that formally represent involved cyber-physical components. The thesis suggests a *four-tier ontology* that acts as a common language describing ITSoS operations.
  - A consistent method by which stakeholders can use the reference model to define and adjust abstract ITSoS plans. The thesis suggests a *hierarchical task analysis* approach to formally describe these abstract plans.
  - An *execution engine* to compose and coordinate the constituent cyber-physical components of the ITSoS. The thesis suggest an architecture illustrating the main component of the engine.

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