PROMENADE:

Platform for Resilient Multi-modal Mobility via Multi-layer Networks & Real-time Big-Data Processing

Angelo Furno
LICIT (UDL, IFSTTAR, ENTPE), France

Workshop on multi-source data analysis for mobility reconstruction
November, 8th 2019

DATA-DRIVEN
RESILIENT MOBILITY

IFSTTAR

ENTPE
L'école de l'aménagement durable des territoires

LICIT

Today's agenda

09:00-09:30	Coffee break
09:30-10:00	*Introduction of the PROMENADE project* (**Angelo**, LICIT Researcher)
10:00-10:30	*Zonal-speed estimation via mobile phone data* (**Manon**, LICIT PhD student)
10:30-11:00	*Point on Orange data collection: problems and projects to come* (**Cezary, Dung**, Orange Labs)
11:00-11:45	*Mobile phone data analysis: state of the art and opportunities* (**Marco**, CNR-Italy Researcher)
11:45-12:15	*Social segregation with CDR 2007 data* (**Lino**, INSEE researcher)
12:15-13:30	Lunch
13:30-14:00	*Home detection with CDR 2007 data and Stop Detection with Signalling data* (**Zbigniew & Bruno**, Orange Labs)
14:00-14:30	*Human mobility and epidemic spreading* (**Stefania**, Orange Labs)
14:30-15:00	*Presentation of current results related to PROMENADE WP2* (**Loïc**, LICIT PhD student)
15:00-15:30	*Discussion on future directions for WP2* (**all**)
15:30-15:45	Point on recruitment of postdocs/PhD students/stages (**all**)
15:45-16:00	Debriefing and conclusion (**all**)

Outline

1. **Project Context**
   - Project Identity
   - Research Team
   - Research Goals
   - Research Issues and Levers

2. **Methodology and Implementation**
   - Research Axes
   - WPs and Tasks
   - Platform Architecture

3. **Zoom on WP2**
   - First Results (by Loic BONNETAIN)

2.
PROJECT CONTEXT

Project Identity

- AAP ANR JCJC 2018
  - CES 22 - Mobilité et systèmes urbains durables
- Duration
  - 3 years (scientific start on Feb. 2019)
  - 4 years-extension has been recently agreed
  - end by January 2023
- Budget
  - Project costs (including all human resources): 750k€
- CDD Resources associated to the project
  - 3 PhD students
    - **1 funded by ANR (Cecile DANIEL)**
    - **2 funded by Ministere Transition Ecologique et Solidaire** (ENTPE)
  - 18-months + 12-months postdoc
    - **funded by ANR**
    - **Recruitement is on-going, but possibility to transform it into**
      - **a PhD Thesis**
      - **+ 12 months postdoc**

- Academic and Industrial Partners
  - University of Illinois at Chicago (US)
  - CNR-IEEIT (Italy)
  - INSA-Lyon, INRIA (France)
  - University of Sannio (Italy)
  - Orange Labs (France)

Research Team

Institution	Name	First name	Current position	Role & responsibilities in the project	Involvement (person. month)
ENTPE (France)	**FURNO**	**Angelo**	**Researcher**	**Principal Investigator;** **Project Coordinator;** Contributor in all WPs; PhD co-director (EH, LB, ANR_PHD)	27
IFSTTAR-ENTPE (France)	EL FAOUZI	Nour-Eddin	Research director, HDR	PhD director (EH, LB, ANR_PHD); Contributor WP0, WP1, WP2, WP3	9
University of Sannio (Italy)	ZIMEO	Eugenio	Associate professor	PhD co-advisor (ANR_PHD); Contributor WP0, WP1, WP4	3
CNR-IEEIT (Italy)	FIORE	Marco	Researcher, HDR	PhD co-advisor (LB); Contributor WP0, WP2	2
INSA-Lyon, INRIA (France)	STANICA	Razvan	Associate Professor	PhD co-advisor (LB); Contributor WP0, WP2	1
Orange Labs (France)	SMOREDA	Zbigniew	Sociologist, Researcher	Postdoc co-advisor (ANR_POST); Contributor WP0, WP2	1
University of Illinois at Chicago (United States)	DERRIBLE	Sybil	Associate professor	PhD co-advisor (EH); Contributor WP0, WP1, WP3	3
ENTPE (France)	BONNETAIN	Loïc	Phd Student (from Sept.'18)	Contributor WP0, WP2, WP4	36
ENTPE (France)	HENRY	Elise	Phd Student (from Sept.'18)	Contributor WP0, WP3, WP4	36
ANR-funded	DANIEL	Cecile	PhD Student (from Dec.'18)	Contributor WP0, WP1, WP4	36
ANR-funded	TBD	TBD	Post-doc/Research Engineer (from Mid. 2020)	Contributor WP0, WP1, WP4	18

Research Goals

- **General Goal**: contributing to resilient, efficient and sustainable urban mobility via novel data-driven scalable, real-time and extensible solutions in large-scale “smart” city environments

- Three **sub-goals** merged in an **extensible platform**
  - **advanced modelling and understanding** of the **dynamic inter-relationships proper to the multi-modal transport offer** via **temporal multi-layer graphs and network mining**
  - **finer-grained and larger-scale dynamic estimation** of **travelers' demand, human presence and typical/atypical patterns** via **machine learning and multi-source data**
  - **quantification and improvement of the resilience** of **mobility networks subject to hardly predictable events** via **simulation of stress scenarios & adaptive control strategies**

Research Questions and Levers (1)

- Can we more **accurately and more dynamically estimate users' travel demand** and mobility habits, even in real-time?
  - **Highly variable mobility behaviors (popular route/mode choices, motifs + OD flows)**
  - **Multi-modality plays a central role for mobility in urban areas**

- How to deal with that?
  - ➢ join the potential of **massively-collected multi-source data**
    - ➢ e.g., **mobile phone data**, Floating Car Data, Smart-card data, taxi data, real-time feeds on traffic, …
  - ➢ leverage most recent advances of **ML with multi-source urban data**
    - ➢ e.g., ensemble & multi-view learning, Bayesian approaches, deep learning, …
  - ➢ exploit the potential of **parallel computing, big data and IoT technologies**
    - ➢ e.g., Hadoop, Spark, Neo4J, lambda/kappa architectures, …

Research Questions and Levers (2)

- Can we quantify, anticipate and **reduce the impact of hardly-predictable events** on multi-modal transport infrastructure?
  - **Mobility highly vulnerable to weather events**
  - **Insufficient knowledge of mobility patterns in atypical situations**

- How to deal with that?
  - ➢ **complex networks** as a light-weight modelling framework
    - ➢ weighted attributed temporal graphs to jointly tracing the dynamics of both mobility offer and demand
  - ➢ **simulation and stress testing** to measure the impact of extreme events/daily perturbations
    - ➢ novel metrics in simulated contexts to dynamically characterize network resilience
  - ➢ **adaptive control strategies** to dynamically modify the offer and absorb the demand
    - ➢ flexible deployment of alternative (multi-modal) mobility solutions in presence of perturbationås

Research Questions and Levers (3)

- Can we **support citizens and service providers with an efficient, scalable and extensible smart-city platform?**
  - **Strict non-functional requirements**
  - **Large-scale, high-frequency streams of IoT data**
  - **Highly heterogeneous business requirements**

- How to deal with that?
  - ➢ Continuous integration of software **development and operations**
    - ➢ OpenShift + Kubernetes (operations) + Helm (deployment) controllers to implement DevOps support
  - ➢ **IoT and cloud-computing support** for real-time data collection & online/offline processing
    - ➢ Artemis + Kafka + Apache Flink to perform IoT data stream-based analytics
    - ➢ Artemis + Kafka + Neo4J + Spark to perform offline analytics
  - ➢ **Load distribution, parallelism and redundancy** for strict non-functional requirements
    - ➢ Edge + Fog computing to support computation on the network edges, Spark for cluster-based computation

PROMENADE Recap: mission and novelty

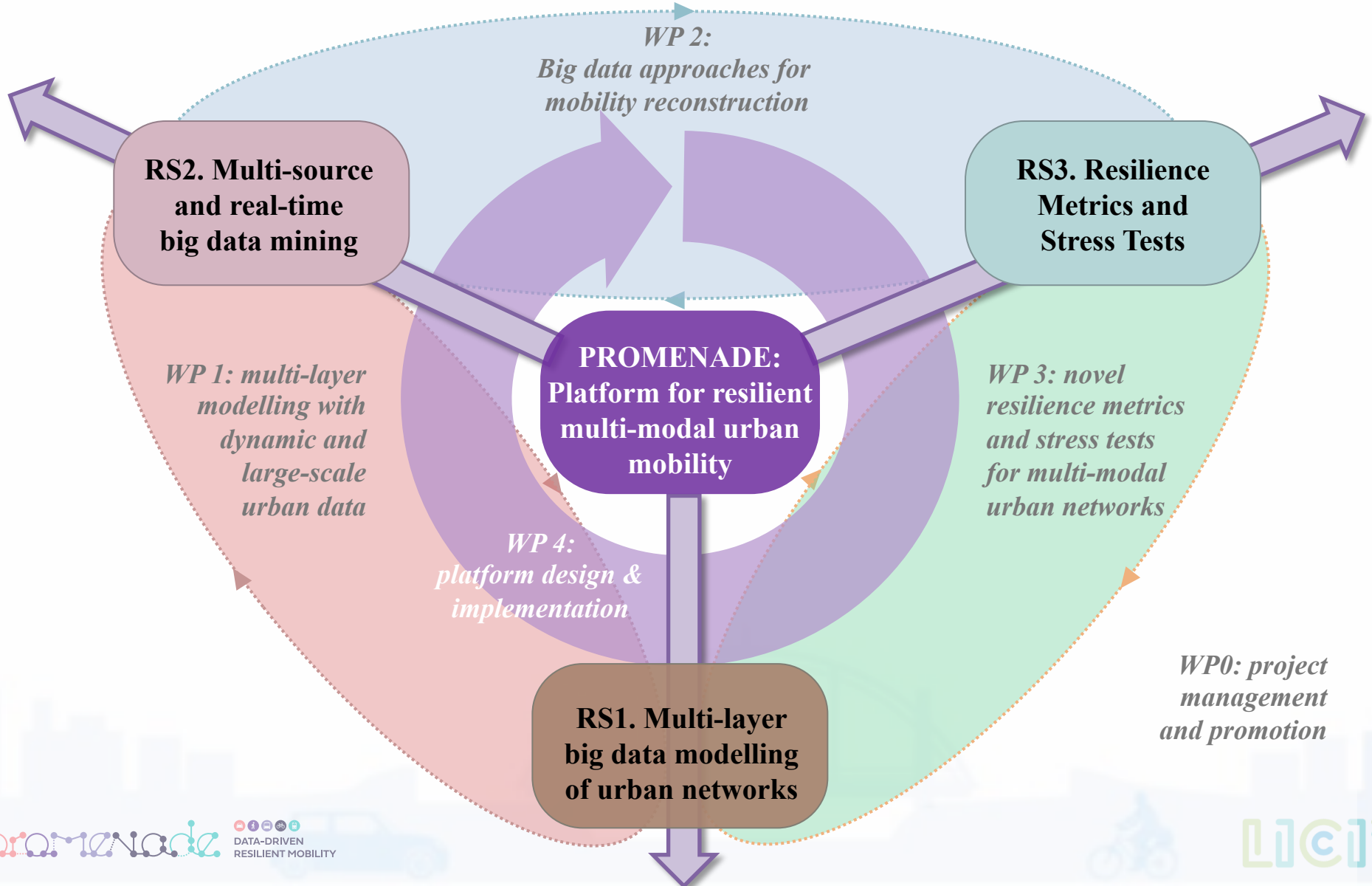
- **Mission** of the PROMENADE project:

  to devise a holistic, real-time, data-driven extensible platform for efficient, resilient and smart monitoring & management of multi-modal urban transport

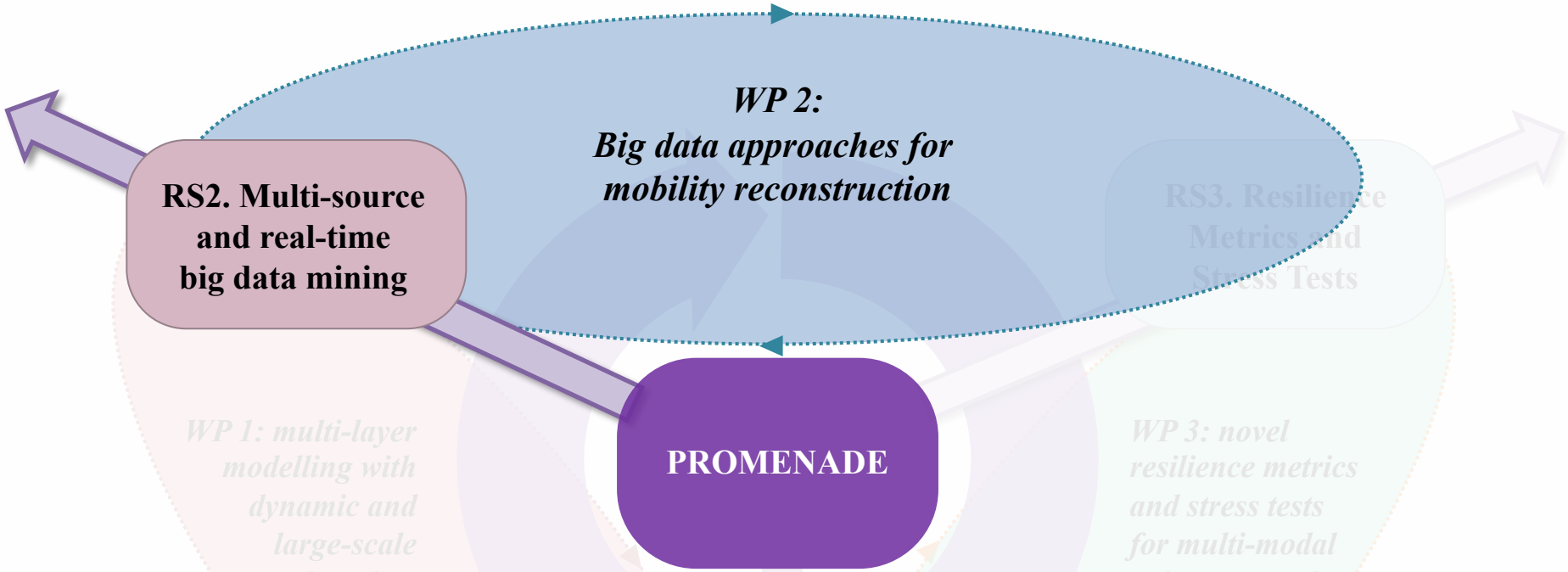
- What's new?
  1. **Complex-networks modelling approach for large-scale smart cities dynamic data**
     - to overcome static, topology-only, single-mode traditional models
  2. **Multi-source, real-time data analytical framework to improve mobility understanding**
     - jointly leverage the potential of mobile phone data, real-time sensors' data, social network data
  3. **Resilience assessment and augmentation tools in multi-modal settings**
     - stress, simulate, quantify and dynamic control strategies
  4. **Open-source extensible IoT-based, microservices-based monitoring platform**
     - IoT, Fog, Cloud, DevOps, Steam-processing technologies

3.
METHODOLOGY AND IMPLEMENTATION

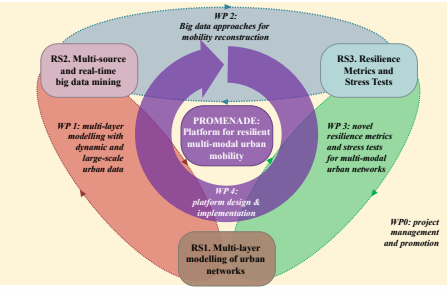
PROMENADE: Three Research Axes (RS) and five WPs



PROMENADE: Zoom on RS2/WP2



Gantt Diagram



Feb. 2019 — Nov. 2019

WPs	Leader	Tasks	Task Leader	YEAR 1												YEAR 2												YEAR 3											
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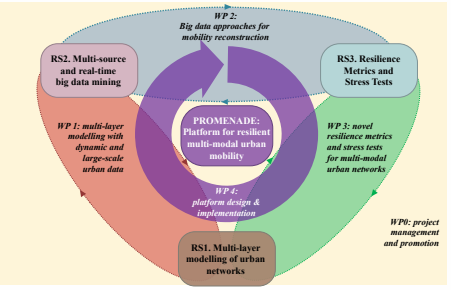
Phd1

Phd2

Phd3

Post doc

PROMENADE: Zoom on RS2/WP2



Feb. 2019 Nov. 2019

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Phd1

LOIC BONNETAIN

Phd3

Post doc

WP2: Big data approaches for mobility reconstruction

- **Task T2.1: Large-scale Mobile Phone Data Analysis for Urban Mobility Reconstruction**
  - leveraging Orange large-scale mobile phone passive data to
    - reconstruct spatio-temporal representations of travel demand, traffic indicators and user behaviors
- **Task T2.2: Multi-Source Urban Data Mining**
  - enhanced mobility reconstruction via multiple sources of large-scale urban data
    - joint processing of smart card data, loop detectors data, GPS data for complex pattern detection
- **Task T2.3: Real-time Urban Data Mining**
  - leveraging real-time data streams in machine learning tasks
    - for identifying and predicting mobility patterns related to atypical events

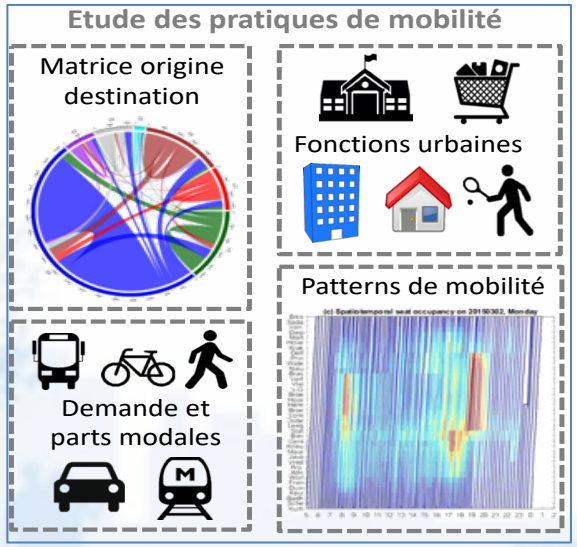
- Thesis title: ***Modélisation des dynamiques de mobilité urbaine fondée sur les données massives et multi-sources***

position hold by Loic BONNETAIN (ENTPE) since Oct. 2018

RS2: multi-source real-time big data mining for augmented mobility understanding

RS2. Multi-source and real-time big data mining

- Jointly mining multi-source data: why?
  - reduce the inaccuracy and incompleteness of current mono-source estimations
  - cross-correlate different datasets to discover complex behaviors and multi-modality patterns
  - three research dimensions
    - individual vs. aggregate behaviors + typical vs. abnormal behaviors + offline vs online analyses



…interesting isolated approaches for mining mobile phone data to reconstruct itine-raries in urban areas recently appeared in the literature [Asgari et al, Darmian et al.]

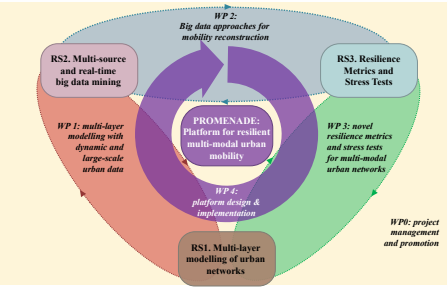
…need to explore big data fusion approaches to complement the information provided by such data, increasing their spatio-temporal granularity *[Zhang et al.]*

…urgent need to move towards novel real-time big data solutions

RS2/WP2: available data

Type of data	Description	City	Source	Status
Mobile Phone Data (CDR)	Hourly number of calls and SMS per Orange base station for one year (2017)	Lyon and Paris	Orange	**Available**
Mobile Phone Data (Signaling data)	Multiple months (in 2017 and 2018) of anonymized individual network signaling data (for 2G, 3G and 4G antennas); **CANCAN data for 16 Mars-15 June 2019**	Lyon and Paris	Orange	**Available**
Mobile Phone Data (Internet Session Data)	Multiple months (in 2017 and 2018) of anonymized individual Internet sessions reports (number of down/up bytes per 6-minutes). **CANCAN data for 16 Mars-15 June 2019**	Lyon and Paris	Orange	**Available**
Mobile Phone Data (Base stations)	Antennas' positions and technology; Simplified theoretical model of geographical coverage	Lyon and Paris	Orange	**Available**
GPS trajectories	GPS data collected every second for a population of approx. 30 users in 2017. **Floating car Data (Coyote-Mediamobile) from Oct 2017 to Sept. 2018 for Lyon + from Mars to June 2019 for Paris and Lyon**	Lyon and Paris	LICIT, MediaMobile	**Available**
Traffic states (Vehicle counts)	Historical and **real-time** counting data from loop detectors; Position of Detectors	Lyon	Lyon Metropole	Agreed
Smart card data	**AVL (automatic vehicle location) : Bus and tramway** **AFC (Automated fare collection): paper tickets + card** **for 2017 in Lyon**	Lyon	Sytral-Keolis	**Available**
Taxi GPS data	**Two years of historical GPS traces from the taxi company Taxi-Radio (2011-2012)**	Lyon	LICIT	Available
Real-time road events	Text messages related to events associated to the road network (real-time)	Lyon	Lyon Metropole	Agreed
Bike sharing system	**Real-time and historical data** on the usage of bike stations	Lyon	Lyon Metropole	Open access
Census and travel data	Enquêtes ménages déplacements de l'aire lyonnaise (2006, 15); Enquête Déplacements Régionale (2012-15) ; Similar data are accessible for Paris	Lyon and Paris	Lyon Metropole DRIEA	Open access/ agreed
PrivaMov and Mobicampus datasets	Aggregate and anonymized data collected via an Android tracking app (GPS trajectories, battery consumption, phone usages for more than 10 users).	Lyon	LAET, CITI	Agreed
Meteorological data	Historical meteorological data on French cities	Lyon and Paris	MeteoFrance	Agreed

Gantt Diagram



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Phd1

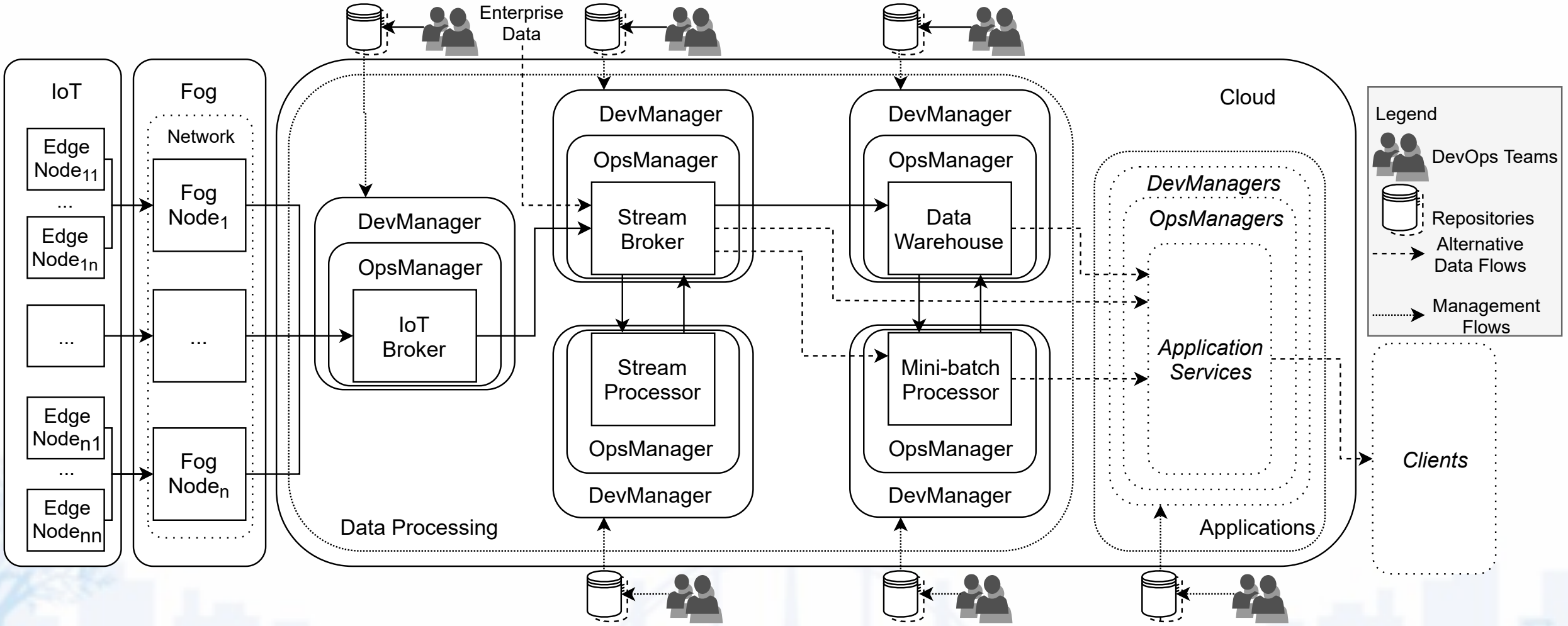
Phd2

Phd3

Post doc

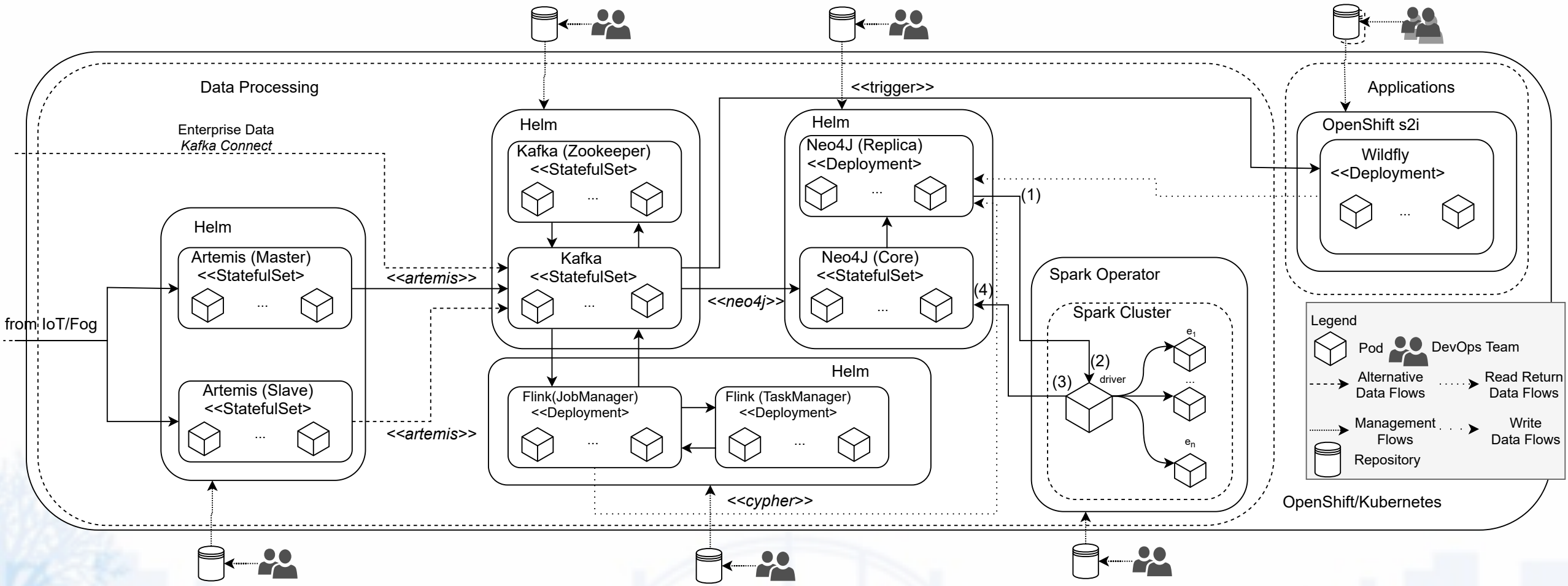
High-level Architecture of PROMENADE

WP 4: Platform Design and Implementation



Technological choices for PROMENADE

WP 4: Platform Design and Implementation



IoT and fog layers are emulated for now by re-playing offline data

3.
ZOOM ON WP2 FIRST RESULTS (LATER BY LOIC BONNETAIN)

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4.
POINT ON PHD AND POSTDOC RECRUITEMENTS

Upcoming Recruitements

- **PROMENADE (ANR JCJC)**
  - 18-months **Postdoc**
    - Starting from **Winter/Spring 2020**
    - Expected work: real-time multi-source data mining + platform development
    - Profile: machine learning / distributed systems
  - 12-months **Postdoc** (from margin)
    - Starting from **Spring/Summer 2021**
    - Expected work : complex network modelling and mining, extreme weather simulation and resilience evaluation
    - Profile: complex networks / physics / traffic simulation

- **DISCRET (ANR FLASH JO2024)**
  - 18-months IFSTTAR/Orange **Postdoc**
    - Starting from jan-2020
    - Work: anomaly detection from mobile phone data in JO2024
    - Profile: data mining / applied maths / statistics
  - 12-months UTT **Postdoc**

Upcoming Recruitements

- **MOBITIC (ANR PRCE)**
  - 24-months IFSTTAR/**INSEE Postdoc** (GRETTIA et/ou LICIT en co-encadrement)
    - Starting from October 2021, if proposal is accepted
  - 36-months IFSTTAR/**INSEE PhD** (GRETTIA et/ou LICIT en co-encadrement)
    - Starting from October 2021, if proposal is accepted
  - 12-months Orange **Postdoc**
  - 18-months Geographie-Cité **Postdoc**
  - **PROBABLY:** 36-months IFSTTAR LICIT/GRETTIA PhD Student (probably funded by IFSTTAR)
    - PhD subject submitted today to IFSTTAR
    - Starting from October 2021, if proposal is accepted