BONVOYAGE

From Bilbao to Oslo, intermodal mobility solutions, interfaces and applications for people and goods, supported by an innovative communication network

Research and Innovation Action GA 635867

Deliverable D1.2:

Project Vision and Roadmap v1

Deliverable Type:	R
Deliverable Number:	D1.2
Contractual Date of Delivery to the EU:	31/10/2016
Actual Date of Delivery to the EU:	31/10/2016
Title of Deliverable:	Project Vision and Roadmap v1
Work package contributing to the Deliverable:	WP1
Dissemination Level:	PU
Editor:	CNIT
Author(s):	Andrea Detti (CNIT), Nicola Blefari Melazzi (CNIT), Maria Bianco (CNIT), Giuseppe Tropea (CNIT), Giuseppe Piro (CNIT), Francesco Sorvillo (Trenitalia), Claudia Rosano (TRIT), Silvia Canale (CRAT), Lorenzo Ricciardi Celsi

	(CRAT), Tiziana D'alfonso (CRAT), Carlo Mannino (SINTEF), Andrea Vassiliev (CEA), Etienne Labyt (CEA), Emilio Calvanese Strinati (CEA).
Internal Reviewer(s):	Ignacio Gonzalez Fernandez (ATOS)
Abstract:	This deliverable is version 1 of the Project Vision and Roadmap; it is updated along the project's lifespan by means of Internal deliverables and will be consolidated at the end of the project with version 2. This report is compiled starting from the Description of Work document, and taking into account results generated within the project, other relevant scientific, technological or market developments, and the long term strategies of the EU and project partners. The deliverable includes three main sections: i) what is the ideal vision of the project and related exploitation and impact; ii) how we plan to realize that vision; iii) what we did so far.
Keyword List:	Project Vision; Roadmap; Objectives; Scientific, Market and Social aspects; Impact, Work performed

TABLE OF CONTENTS

List of Figures

List of Tables

Abbreviations

ABBREVIATION	DEFINITION
IoT	Internet of Things
GTFS	General Transit Feed Specification
ITS	Intelligent Transport System
MB	Management Board
GB	General Board
CTO	Chief Technical Officer
P2P	Peer to peer

Table 1: Abbreviations

BONVOYAGE Glossary

Table 2 lists and describes the terms that have been considered relevant in this deliverable.

BONVOYAGE GLOSSARY	
TERM	**DEFINITION**
Vision Statement	A Project Vision Statement is an idealistic view of the desired outcomes to be produced for the business after successful project completion.
Project Roadmap	The Project Roadmap is a high level overview of the project's goals and deliverables presented on a timeline.
Federation	A federation is a group of computing or network providers agreeing upon standards of operation in a collective fashion, so that inter-operation of such group of distinct, formally disconnected networks, which have different internal structures, is obtained.

Table 2: BONVOYAGE Dictionary

1 Introduction

1.1 Deliverable Rationale

Having a clear project vision is very important to the success of complex initiatives such as R&D multi-partner, multi-objective collaborations. BONVOYAGE additionally has an inter-disciplinary nature, cross-fertilizing research between the science of transport networks and the science of telecommunication networks, which poses more burdens to the scientific coordination work.

The vision and roadmap are essential to distribute a common understanding of where the project is going within the Consortium itself, first and foremost. It also serves the purpose of communicating such common understanding outside the project, publicly, and to the project's reviewers and funding entities.

1.2 Quality review

VERSION CONTROL TABLE			
VERSION N.	**PURPOSE/CHANGES**	**AUTHOR**	**DATE**
0.1	Draft index of the document	Maria Bianco	07.04.2016
0.5	First consolidated TOC and draft sections 1-3	Nicola Blefari Melazzi	27.04.2016
0.9	Final content and structure	Giuseppe Tropea, CRAT, SINTEF, TRIT, CEA	20.10.2016
0.9.1	Review and mapping between parts	Andrea Detti	22.10.2016
0.9.2	Sync with Quarterly Reports	Maria Bianco	23.10.2016
0.9.3	Tables, Figures	CNIT	26.10.2016
0.9.5	Integration of review feedback	CNIT	26.10.2016
1.0	Final review loop	Giuseppe Tropea, Nicola Blefari Melazzi, Ignacio Gonzalez	30.10.2016

1.3 Executive summary

1.3.1 Deliverable description

This deliverable reports the first version of the Project Vision and Roadmap of the project; a second version will be delivered at the end of the project. The document starts from the original Description of Work document, and takes into account results generated within the project, other relevant scientific, technological or market developments, and the long-term strategies of the EU and project partners. Thus, it includes parts of the original proposal, updated when needed, concise description of work performed, the current status of the project roadmap, and new/updated concepts.

In some cases this document duplicates information provided in other deliverables, but its aim is to concisely describe the project as a whole, and publicly. More details can be found in project deliverables (http://bonvoyage2020.eu/results/deliverables/), which are quoted in this document by their official abbreviation, Dx.y for final deliverables and Ix.y for internal, intermediate deliverables. All deliverables are available for reviewers and advisory board members, while only those marked as "P(ublic)" are publicly available.

As for the organisation of the document, after a brief introduction, in Section 2 we report the vision of the project, detailing major features and expected benefits, potential market, and comparison with other solutions. In Section 3, we describe how we plan to reach our vision, by: i) listing specific objectives; ii) specifying scientific/technical, market and societal aspects of the overall vision; iii) providing updated roadmap, and risks. Finally in Section 4, we give an account of the work performed so far, including both design and lab prototyping activities and related expected impact.

1.3.2 Summary of results

This document summarizes the vision and plans of BONVOYAGE and the work performed so far, providing in a single document a bird's eye view of the project. The second version of this deliverable, due at the end of the project at month 36, will provide a complete picture of our achievements.

2 Vision Statement

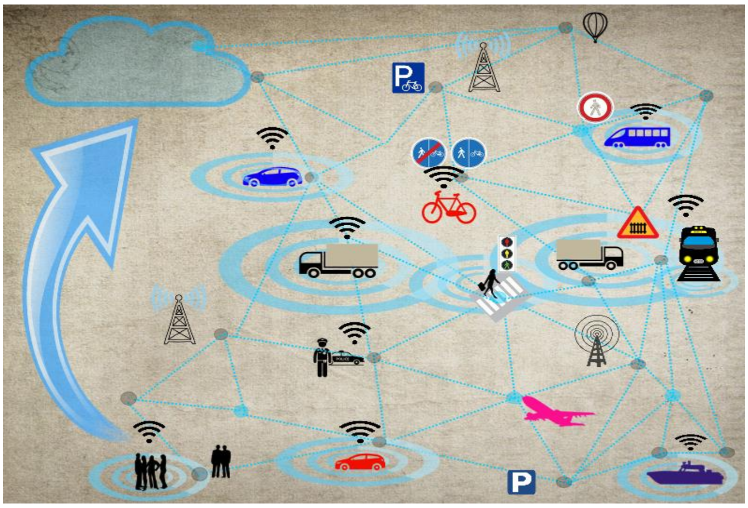
For several years now, journey-planning websites have helped transport operators and public authorities to improve the quality, the ridership, and revenues of transportation services. Traditionally, these instruments have been conceived as *closed systems*, and planning services are often times outsourced to a small number of specialist providers.

Quite recently a growing tendency to publish and share transportation data directly on the web has emerged. As an example, Google is trying to define a standardized format, namely GTFS, which exposes public transportation schedules and related geographic information, while EU-backed formats such as DATEX II are mature and extremely expressive.

This new trend is laying the foundation for an **emerging *open source* model for the Intelligent Transport Systems**, which brings to two fundamental innovations.

First, diverse and competing suppliers (including one-man app developers) can be able to implement their own applications with the data. Consequently, wide access to travel-centric data is supporting the *intermodality* of the solutions delivered by the application, because it simplifies and promotes the configuration of journeys **encompassing different transportation means and domains**.

Second, we witness a pervasive integration of sensors into cars, trucks, and other transportation units, which can be networked and exploited for monitoring of traffic and road conditions, predicting arrival and departure information, ensuring traffic safety, and so on. As a result, it is expected that a huge number of ***crowd-sourced* data (coming from websites, data-centres, sensors, vehicles, goods and people on the move) will shortly be adopted** in ITS applications, giving birth to innovative enhancements, which are yet to be fully comprehended.



What are the obstacles along the path towards these innovations?

Many of the centralized journey-planners currently available in the market have the limitation that the scope of route searches is geographically restricted to a region or a metropolitan area or specialized for one transport mode. Given the speed of networks and the storage capacity of today's commodity computer hardware, some centralized applications are emerging (Google Maps/Transit, rome2rio), which try to scale continent-wide or worldwide and to multimodal travels. Although theoretically possible, to organize and exchange raw transit and schedule data for an entire continent, such that each planner instance has access to all raw schedule data, is practically not feasible when:

- real time constraints are to be taken into account;
- user profiles are involved;
- different optimization schemes are to be applied, depending on localities and region-specific constraints;
- rate of transit data updates is different between different regions;
- there exist some concerns about openness of data on the part of the large, sometimes cautious Transport Operators;
- it would be hard to convince transit businesses or authorities about their need to allocate funds to ITS applications with a worldwide scale, even though the costs of computational resources are becoming cheaper.

This is why the European Union Directive 2010/40/EU draws a **legal framework for developing specifications to make ITS interoperable across borders**.

Furthermore, the ITS business does not immediately achieve openness of the solutions and interoperability just by adopting standardized formats for transit data or by developing new applications on top of available open source components. Beyond that, easy and efficient data dissemination is required when external players, transport operators, sensors, passengers, and other data sources, may publish and use travel data to plan journeys, and to manage them, on any scale. As an example, OAG Aviation (the world's largest network of air travel data) not only provides schedules in any format the customer requires, but offers real-time data feeds and alerts with a schedule changes notification system, adopting an incremental publish/subscribe scheme.

In addition, the highly heterogeneous data sources, including data-centres, sensors, vehicles, goods and people on the move, their distributed and mobile nature, as well as the coexistence of heterogeneous network protocols, **calls for an innovative information delivery paradigm**, which simplifies the development of ITS application when compared with traditional use of the current TCP/IP Internet architecture.

The vision of the BONVOYAGE project is twofold:

- for the end-users, to **provide the best information to go from a place to another, before and during the travel**, door to door, by using any combination of any transport means, both for people and goods, taking into account real-time conditions and user preferences;
- for the EU and ITS community, **to provide an open and federated architecture able to cluster planning services and data sources**, exploiting the functionality of an innovative information-centric networking approach.

To this end, the project is designing, developing and testing a platform that integrates travel information, planning and ticketing services, by automatically analysing non-real-time data from heterogeneous databases (on road, railway and urban transport systems); real-time measured data (traffic, weather forecasts, data from smartphone and wearable sensors); user profiles; user feedback. The platform is supported by an **innovative communication network** that collects and distributes all the data required to optimize a travel.

2.1 The BONVOYAGE Platform

The project focuses on the design, development and test of **three main system components**: i) **applications and services**, in multimodal, dynamic, distributed, multiparty, open scenarios; ii) a **travel optimizer tool** providing travel instructions, which are personalized for each user, adapted in real time to current transport conditions of a given context, and optimal for that user and that context; iii) a **communication network**, which provides large scale search and delivery of all relevant data, from schedules to sensor-generated and user generated real-time information.

In the following we first describe in more details each of these components, then summarize their more innovative/appealing characteristics and finally we conclude by discussing possible exploitation of our work.

2.1.1 Applications and services

Applications and services allow external heterogeneous actors to seamlessly interact with the BONVOYAGE platform. They provide functionalities to integrate and adopt services of transport operators into the platform and a mobile application to interact with end users. The mobile platform provides the user with real-time route information and collects relevant user feedback using participatory sensing while traveling.

The mobile application enables users to find the best way to go from one place to another taking into account the users personal needs and preferences in terms of schedule, duration, costs, transport means, reliability, transport mode related to low user's stress level, etc. The application follows complementary interface and interaction design allowing users to intuitively request required information and receiving personalized multimodal travel routes. During the trip, the application guides the user with required information and reacts on dynamic, real-time conditions that interrupt and affect the on-going trip. User feedbacks will be collected via unattended and attended feedback functionality taking into account new trends such as smart wearables. The user behaviour and feedback data are used to derive data-driven user profiles that are used to customize services and travel solutions. The feasibility of the developed mobile platform will be tested and evaluated in realistic open scenarios.

In order to access and use external services and data the BONVOYAGE platform provides integration and adaption mechanisms to integrate technology dependent interfaces. An adaption framework for intelligent transport functionalities allows to easily integrate and personalize external transport operator services for BONVOYAGE users. This functionality ensures flexibility and expandability of the platform to integrate other transport services.

2.1.2 Travel optimizer

The travel optimizer is a core function of the BONVOYAGE platform. Our solution is a collaborative framework for distributed optimization services. This approach enables the necessary scalability to handle continent-wide travel networks combined with personalized travel preferences. At the same time it also enables fast response to real-time events. Hence, the resulting solutions are truly intermodal, handling combinations of any private and public modality in the same journey. The existing, alternative technology heavily relies on extensive pre-processing, which limits the possibility to exploit real-time information as well as personalized user profiles. The BONVOYAGE travel optimizer goes beyond these limitations thanks to its distributed architecture and its novel algorithms.

2.1.3 Telecommunications network

The highly heterogeneous, distributed and mobile nature of transport data, coming from data-centres, sensors, vehicles, goods and people on the move, calls for a new networking model.

The **current Internet model** is based on the Internet Protocol (IP) and provides users with communication channels between hosts (e.g. a client and a server) that are identified by an IP address. IP network nodes, or routers, forward data among users' hosts on the basis of their IP addresses, which statically determine where they are topologically located in the network. IP routers are blind as to what they are forwarding. Security is provided by securing the communication channels.

Our **alternative reference model** is called **Information Centric Networking** (ICN), a paradigm emerged to overcome some intrinsic limitations of the current Internet. In ICN, the network provides users with access to information by names, instead of providing communication channels between hosts. The idea is to provide "access to named data" as the fundamental network service. This means that all information (e.g. a document, a picture) is given a name that does not include references to its location; then, user's requests for a specific information are routed toward the "closest" copy of such information, which could be stored in a server, in a cache contained in a network node or even in another user's device; finally the content is delivered to the requesting user by the network. With ICN, the communication network becomes aware of the name of the information that it provides and the routing decisions are made on the basis of the information name. This enables nodes to carry out advanced delivery services, like caching and multicasting, thus reducing the resources needed on servers, and improve responsiveness and reliability of applications. In addition, ICN secures the information package itself, instead of securing the communication channels, thus information can be trustily delivered also by untrusted servers or nodes and remain protected also when emerges from a communication channel (e.g. a picture is protected not only while it travels into the network but also after arriving at destination). As a result, ICN: i) improves network efficiency, thanks to in-network caching and information-based routing; ii) naturally supports mobility and multicast communications; iii) eases the operation of fragmented networks, or sets of devices disconnected from the rest of the network (e.g. sensors networks, vehicular networks, social gatherings, mobile networks on board trains, planes, or networks stricken by disaster; note also that ICN could be applied to the whole Internet but also to a subset of it, this is especially useful in our environment); iv) offers simpler application programming interfaces; v) provides an information-oriented security and access control model which is rapidly becoming essential, in a world where all traffic in being encrypted, wreaking havoc with established network mechanisms.

In BONVOYAGE, we are working on three main networking issues.

The first one is to contribute to the design of **basic functionality of ICN**, of which we are among the first designers, including interplay with cloud/virtualization concepts, name to location resolution, routing/forwarding table scalability.

The second issue is to develop a declination of ICN, which we call **Internames**. Internames evolves from ICN's host(s)-to-name model to a name-to-name principle in which names identify both source and destination entities, and names are used to identify all entities involved in communication, not only content but also users, devices, network functions and services. The latter functionality enables easy re-location or duplication or anycast search of service (components) where and when they are needed. Internames also addresses what is probably the most crucial issue of ICN today, namely how to introduce ICN in current networks, easing migration/interworking from/with IP and deployment strategies. In fact, most people agree on the advantages that ICN could bring about, but are also concerned about ICN as a network layer solution, alternative to IP, when facing migration/deployment issues. Another possibility would be to deploy ICN as an overlay to IP, that is to say on top of IP, even if at the cost of increasing complexity and inefficiency. In any case, many argue that that question is not if ICN or similar concepts should be introduced or not, but where (in the OSI stack) and by whom. As recently put by Cisco's Service Provider Mobility CTO: "If the network operator industry fails to create an ICN-like architecture then someone like Google will and they will put it behind the SP's IP transport network". In BONVOYAGE we do not rely on the deployment of ICN at large in lieu of IP, as we can always resort to an overlay solution, but we still work on how to facilitate the deployment of ICN at the network layer. With Internames, travel-centric contents and sensor-generated and user-generated data could be retrieved by using both request-response and publish-subscribe communication models. With the request-response scheme, data are retrieved synchronously. For instance, if a user is interested to fetch a specific travel-centric content (e.g., time-tables provided by a transport operator for a given geographical area), it has to issue a request, which will be forwarded toward the node able to provide the corresponding answer. The publish-subscribe mechanism, instead, is based on an asynchronous interaction: a user issues a subscription request for a sensor-generated data (e.g., weather conditions); then, every time the sensor registers a new value (e.g., the temperature went below 0°C and the road may be icy), the considered source of information and the network itself are in charge of delivering that data to all the subscribed applications. Furthermore, any networking operation is exposed to the application layer through a standardized and scalable middleware interface, namely Internames Service Layer, which hides all the details of the underlay communication technology and simplifies the interoperability among coexistent and heterogeneous network domains.

Therefore, high level applications will be able to use a set of API (useful to search the name of a content starting from a list of meta-data, request a data, announce the availability of a content, make a subscription, and send a push notifications), through which triggering the corresponding networking operations, while ignoring how services/contents are executed/delivered in a heterogeneous network architecture.

The third issue is about a **decentralized large-scale storage system** used for building our georeferenced mobile and web applications, which we call **OpenGeoBase**. OpenGeoBase exploits ICN and Internames to collect and make available georeferenced transport-related data. Basically, OpenGeoBase allows anyone to publish data relevant to a specific geographic area, ranging from transport schedules to sensor-generated or user generated real-time information, but also, point of interests, etc. Then, interested users/travel operators can search and retrieve all data available in such geographic area, which are needed to plan an optimal multimodal trip. Publishers are not forced to upload their data in a central repository but they can keep them in local, distributed repositories, under their control. OpenGeoBase logically puts together all individual repositories and make it easy for users to search for and retrieve the data they are interested in. We call *slice* a space in a set of Repositories and *tenants* the application owners (e.g. journey planners) that can rent a *slice* for their applications. Users of a *tenant* can Create, Read, Update and Delete data on *tenant* repositories. The data base can grow without bounds by merely deploying new servers (horizontal scalability), and ICN takes care of routing the queries towards the best servers and cache the answers to popular queries to speed-up response time. By exploiting ICN's in-network multicasting and caching, massive information describing routes, prices, schedule plan, etc. can be quickly provided to millions of users, also under flash crowd conditions and severe events, such as interruption of a major road, extreme weather, disaster. By exploiting ICN security, the database can secure every piece of information in a customizable way and can include configurable policies as to who and when and where can access the information. As a result, OpenGeoBase is: i) distributed, not requiring a centralized entity, ii) scalable, capable of growing without bounds; iii) secure, every piece of content can be secured in a customizable way and can include configurable policies as to who and when and where can access the information; iv) slice-able, several tenants and users can use it in parallel and independently; v) reliable: no single point of failure; vi) fast.

Finally, all our ICN technology and related applications will be released as open-source code.

2.2 Innovative characteristics

Innovative characteristics of BONVOYAGE with respect to current solutions include:

- supporting different optimality criteria and ranking options of **multimodal** trips (e.g. resulting from a combination of bike+train+plane+bus+on foot), for both passengers and goods
- taking into account **dynamic, real time**, conditions (e.g., delay of trains, construction work on a road, bad weather, user's stress level)
- taking into account **user preferences and profiles**, including dynamic information like preferred transport modes and user's stress level related to different transport modes as estimated from previous travels through data collected by wearable smart sensors and smartphone sensors
- facilitating the **large-scale search, sharing and delivery** of transport solutions and related data among transport providers, travel service operators, applications and users; this is one of the main problems nowadays: how to collect transport information not only from big airlines/train operators but also from all the millions, small scale, bus/local transport/private providers
- allowing transport providers to keep their **data and services in their premises, with their formats and interfaces**, rather than transfer them to a third, centralized party (e.g. Google) and/or to comply with specific format (e.g. GTFS)
- allowing travel operators or applications **to get data directly from the transport providers** rather than from a third party
- allowing any one to **easily publish transport solutions, including private citizens** (e.g. for car sharing purposes, hitching a lift)
- allowing any one to **set up access restriction and privacy policies on published data** and then verify the owner and the authenticity of published data
- allowing any one to **easily exploit all such information** (e.g. anyone can develop an application and become an online travel platform provider).

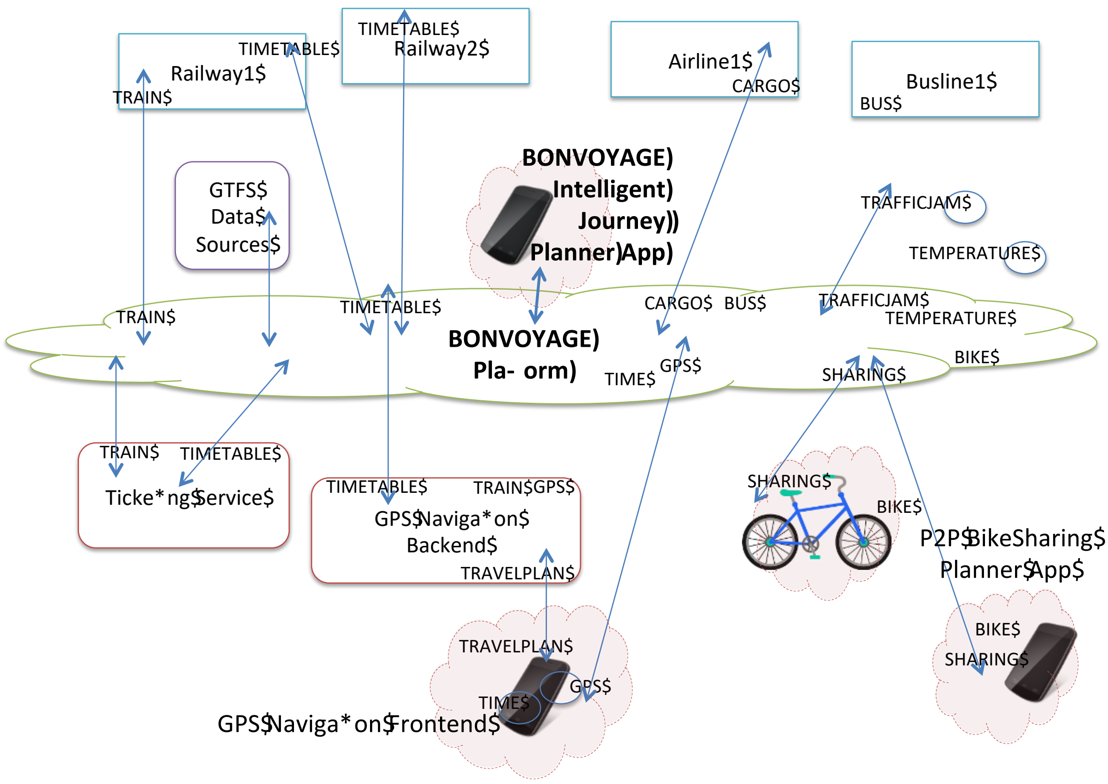


Figure 1: Big picture of BONVOYAGE as an open ITS platform

A big picture of the BONVOYAGE platform is shown in Figure 1 above. External players, transport operators, sensors, passengers, and other data sources (for instance GTFS and DATEX II), may publish and use travel data to plan journeys, and to manage them, on any scale. All the entities use a name-based approach to communicate: all the end-points and contents are identified by names and the network layer exposes ICN primitives.

The innovative characteristics described above lead to the creation of a **truly open platform** supporting the interaction among a large number of actors (i.e., passengers, travel operator, localized journey-planners, sensors, and so on) across the boundaries of organizations and domains, becoming a very powerful enabler of a continent-wide smart-transportation system.

In turn, such open platform allows adopting a truly innovative model in the scenario of journey planners, which is a distinctive feature of our project: that of a **federation of computing or network providers** agreeing upon standards of operation in a collective fashion, so that inter-operation of such group of **distinct, formally disconnected networks, which have different**

internal structures, is obtained; this is a **very important characteristic and innovation of BONVOYAGE**, and we devote the next section to describe it.

2.3 The BONVOYAGE Federated Architecture

A central idea of BONVOYAGE is to implement an open and **federated architecture**, to establish an infrastructure for continent wide travel planning, grounded on an information-centric network layer.

Differently than a generically distributed or P2P system, a federation is a group of computing or network providers agreeing upon standards of operation in a collective fashion, so that inter-operation of such group of **distinct, formally disconnected networks, which have different internal structures**, is obtained.

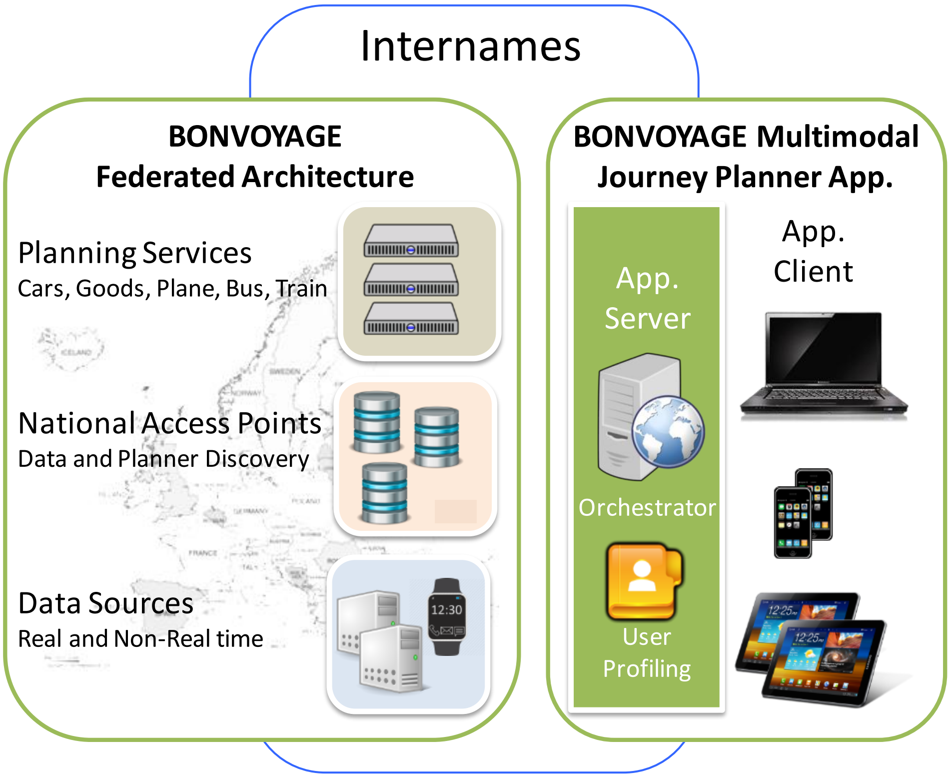


Figure 2: BONVOYAGE federated architecture

Figure 2 describes the BONVOYAGE federated architecture. We have *Clients* that use a multimodal journey planning application supported by an *Application Server*. The Application Server uses a federated architecture formed by: a set of *Planning Services*, i.e. route resolvers, *Data Sources*, and *National Access Points*. Both data and services refer to a given geographical area (e.g. a country) and given transport modes (e.g., car+bus, plain+train, car sharing, etc.).

Planning Services and Data Sources are discovered through a *Discovery Service* offered by the National Access Points.

A declination of ICN, which we call **Internames (see 2.1.3), supports the federation**.

Guided by this federated approach, BONVOYAGE is designing, developing and testing its platform for optimizing multimodal transport of passengers and goods.

2.3.1 The EU Legal Framework

We are using the term National Access Point on purpose. The European Union is acknowledging the difficulties arising from a strictly centralized solution to the problem of continent-wide future-proof ITSs. The Directive 2010/40/EU ("Framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport") establishes a legal framework for developing specifications to make ITS interoperable across borders. The six priority action areas set out by the Directive are:

- Priority action (a): "the provision of EU-wide multimodal travel information services" (This priority action is currently under development: a public consultation has been launched http://ec.europa.eu/transport/themes/its/consultations/2015-its-mmtips_en.htm)
- Priority action (b): "the provision of EU-wide real-time traffic information services (Commission Delegated Regulation (EU) 2015/962 of 18 December 2014).
- Priority action (c): "data and procedures for the provision, where possible, of road safety related minimum universal traffic information free of charge to users" (Commission Delegated Regulation (EU) No 886/2013 of 15 May 2013).
- Priority action (d): "the harmonized provision for an interoperable EU-wide eCall" (Commission Delegated Regulation (EU) No 305/2013 of 26 November 2012).
- Priority action (e): "the provision of information services for safe and secure parking places for trucks and commercial vehicles" (Commission Delegated Regulation (EU) No 885/2013 of 15 May 2013).
- Priority action (f): "the provision of reservation services for safe and secure parking places for trucks and commercial vehicles" (This priority action has been shelved due to lack of sufficient interest in this area).

The delegated regulations on priority actions (b), (c) and (e) require the setting up of a single National Access Point (NAP) and its associated "discovery/search and browse" functionality, by each Member State. This will enable those interested in accessing the data to find it all in one place. Data owners in the public and private sector will be requested to make their data accessible via the national access point.

Each National Access Point will offer a single point of access to the road and traffic data of a given territory or network, which are available for re-use by any potential user. Through the discovery services any user will be able to effectively access the data and find out what data is available (in relation to a specific topic or purpose), where it is stored (and possibly who owns it), how to use it (possible terms and conditions of re-use under specific contractual agreements).

The specifications for priority action (a) is in the final stage of preparation and will most probably refer not only to a national access point but, in addition, to a "linking service" which will enable the service exchange between national travel planning services and the possibility to plan trips continent wide.

We believe that **BONVOYAGE can play an important role in supporting this regulation** and the implementation of the National Access Points, as well as giving relevant input on how to establish an infrastructure for continent wide travel planning, as shown in Figure 2. This way, the project contributes to an open and pan European solution by establishing several collaboration mechanisms between several multimodal planners, towards the realization of the NAP concept established in the EU 2010/40 directive.

In the meantime, Google Transit remains the only viable authoritative option that offers good results for both local transit routes and routes across a nation or continent, and we would like to avoid a scenario where National Access Points, after an unsuccessful experience with their own multimodal planner, prefer to adopt a Google Transit-based solution.

2.3.2 Innovation to the ITS community and EU

Priority actions (b), (c) and (e) require each Member State to set up a single NAP able to perform discovery, search and browse functionality. BONVOYAGE provides a federated architecture enabling the integration of data sources and planning services, **matching the EU directive**. Here we briefly explain how BONVOYAGE constitutes a **global platform for the ITS community** where orchestration of data and planners makes possible to easily setup novel multimodal journey planning applications**.**

BONVOYAGE implements the federated architecture in its key components (see Figure 2): a discovery service, some focused planning services and novel data sources.

Through the **discovery service** authorized users can publish georeferenced information related to their data or planners to make them discoverable, and they can retrieve all information available in an area, which is needed to plan an optimal multimodal trip. Information retrieval can be carried out also in deferred way, subscribing interest on events that occur in given areas, e.g. a new planner or source of information is made available or traffic conditions change. The discovery service is based on a novel spatial database, named OpenGeoBase, which exploits Internames, our version of the Information Centric Network (ICN) layer. In our vision the National

Access Points become the access points of OpenGeoBase. Each country can autonomously manage its own OpenGeoBase servers while being part of a global federated system.

BONVOYAGE offers **a set of planning services** exposing a common interface. The project provides three specialized planners: a multimodal planner able to route people based on real-time conditions, where the plan is continuously updated with new estimates, delays and other incidences; a planner specialized for car sharing and another planner specialized for goods.

BONVOYAGE also deals with novel forms of data sources based on wearable sensors, which measure real-time behaviour of a traveller to assess her stress level or her mode of transport (driving, walking, cycling, etc.).

Clearly the BONVOYAGE architecture can federate a variety of novel planning services and data sources **including the ones developed by other European projects**, thus federating algorithms for travel planning that are able to respect particular local restrictions and area-specific constraints.

2.3.3 Innovation to the end-user

Nowadays, the number of multimodal journey planning applications is still very limited, albeit their undeniable usefulness. Two issues that limit the development of such applications are: the complexity of multimodal planning algorithms and the practical difficulties of retrieving massive ITS data. The BONVOYAGE federated architecture enables developers to easily overcome these impairments, simply orchestrating data or planning services provided by others, so **fostering the diffusion multimodal journey planning applications.**

In addition, BONVOYAGE provides its own **multimodal journey planner applications for people and goods,** which exploits the federated architecture and takes into account specific, **user-profile-based travel preferences** in order to drive multiobjective optimization algorithms, **which communicates with the user both before and during travel**. For instance, before the travel starts a user can be notified if some segment of the planned trip must be changed due to a temporarily cancelled bus stop. Similarily, real-time events are taken into account and notified during the trip. The application exploits a User Profiler Tool whose key difference with state-of-the-art solutions consists in the **automatic learning of user preferences from the user behaviour.** Moreover, crowd-sourced data coming from users is used to optimize travel planning. It comes from two main sources: sensors embedded in the smartphone, wearable sensors (connected watch, wristband, jacket, etc.). This information can be included in the user profile and used by the application to preferentially propose the transport modes with lower stress level, which improves user's well-being during her travels.

2.4 Market Vision

The market vision for multimodal transportation, both for passengers and goods, is an increasingly Interconnected European Space where information on trips and ancillary services are provided by multiple operators and services providers. Today's market related to trip planning is evolving on the basis of these main trends:

- **High quality** required by travellers in choosing transport mode, both for short and long distance. Long-distance travel is a growing market segment. Analysis of the user requirements shows that modes are chosen based on travel costs and time. In this view, moving by car is still the transport mode that presents higher resistance to change in these two factors than trains and buses[1].
- **Integration of long-distance travel with the last urban mile**: travellers are more keen on changing transport mode when it is possible to reach main cities by trains and there enjoy city visits and sightseeing by comfortable urban transports, taxi or car sharing, car pooling and bikes. Better connections with the last urban mile impact even more on commuting trips.
- **One ticketing selling point:** mobile technologies enable the possibility to plan a trip and buying tickets instantly. The possibility to plan an end-to-end trip and buying in just one click all the required tickets increases the inclination of users and on the other hand broadens the offer of services (transportation, touristic information, special events), which the travellers can enjoy along the trip.

As for the movement of freight different trends shall be taken into account:

- **High efficiency** required by freight operators in choosing main routes for moving goods. Currently the higher share of freight transportation mode is related to road traffic with 75.4%, while train counts 18% (the percentage share of each mode of transport in total inland transport expressed in tonne-kilometres (tkm); the remaining share is related to inland waterways[2].
- **Fast Connections** to ports mooring ocean shipping vessels with high capacity. Ocean shipping moves nearly 80% of international trade and the ports' capacity to moor such big vessels, as consequence, implies a huge traffic by road, as reported above. Increasing multimodality services and complementary rail services can split such traffic on different modes such as rail motorways and mayor transport corridors[3].

BONVOYAGE has the ability to:

- overcome the **heterogeneity** of data and to provide them in an open platform;
- provide travel **planning solutions that include local, area-specific regulations and restrictions**, by means of the federated architecture;

[1] "Intermodal Passenger Transport in Europe. Passenger Intermodality from A to Z". LINK project.
[2] Eurostat source
[3] Trans European Transport Networks (TEN-T)

- design tariff schemes for multi-modal long-distance trips operated by a partnership between air transport and high-speed rail, having (i) **pricing rules that allow the transport operators that build the partnership to increase their profits**; (ii) benefit for passengers and (iii) reduction of pollution.

This promptly makes it possible to provide travellers and freight operators with journey and route plans with the following added values:

- Higher quality of life in travelling on long distance and urban last miles, based on user needs (including users with special needs).
- Better planning of logistics for movement of freight that ultimately improves inventory management with just-in-time delivery, which is what supply chains critically depend on.

2.5 Societal Vision

The EU transport policy aims at a form of mobility that is sustainable, energy-efficient and respectful of the environment. These goals can be achieved by using multimodal transport that combines optimally the various modes of transport, exploiting each one's strength and minimising the weaknesses. The European Commission hence pursues a policy of multimodality by ensuring better integration of the transport modes and establishing interoperability at all levels of the transport system (see https://ec.europa.eu/transport/themes/logistics-and-multimodal-transport/digitalisation-transport-and-logistics-and-digital-transport-and_en).

More broadly, the societal challenge "Smart, Green and Integrated Transport", aims at minimising the impact of transport systems on climate and the environment, improving mobility in urban areas, but also promotes the global leadership of Europe in transport through smart control systems. Relevant to the project are also, indirectly, the challenge "Climate action, environment, resource efficiency and raw materials" and "Secure, clean and efficient energy".

The main inspiring ideas from the above challenges that have influenced the societal vision of BONVOYAGE are those of a:

- **Reduction of the dominance of road transport** (83% of passengers and 72% of freight are still moved on roads), and consequent reduction of CO2 emission.
- Smart city where **traffic congestion is lowered** by parking management, bike and car sharing promoted by municipalities, and a smart management of urban public transport.
- Personalised trip solution that improves travel experience for a growing number of elderly people, as well as for **persons with special needs** (kids, people with disabilities).
- Economic growth sustained by the creation of new **added value services** in the field of ITS.

The above objectives are captured by BONVOYAGE, because it enables operators to have 'demand-response' systems where, based on the needs of a dynamic grouping of users with common profiles, transportation facilities may be dynamically created to meet demand. For instance, an itinerary can be designed by including the desire expressed by the user to limit energy usage and carbon footprint in the platform's multi-objective optimization tool. Wearable electronics and eHealth devices are used to provide real-time automatic feedback under the form of **participatory sensing**, to monitor the wellness of the travellers and possibly change or adapt the on-going trips.

Furthermore, the BONVOYAGE **score policy** is aimed to influence users mobility choices with the ultimate goal to reduce the environmental impact of the travel solutions selected by the users, pushing them to select travel solutions comprising transports with a low level of CO2 consumption. This objective is achieved through the assignment of scores on the basis of the means of transport selected by the users, and offering the possibility to use the scores to obtain prizes, awards and discounts.

2.6 Relationship to Current Initiatives and Contribution

BONVOYAGE is one the 12 projects belonging to the first phase of the H2020 Intelligent Transport Systems "Mobility for Growth" EU call, which will globally span a total budget of €216.2 million, and articulates in 17 topics. The Mobility for Growth call is part of the Horizon 2020 Smart, green and integrated transport challenge. It addresses the following transport challenges:

- mode-specific (aviation, rail, road, waterborne);
- transport integration specific challenges (urban, logistics, intelligent transport systems, infrastructure);
- cross-cutting issues.

Targeting cross-fertilization among different groups and projects, especially within the above mentioned call, BONVOYAGE has established liaison with other related EU and international research projects, leveraging both the contacts already established by project partners as well as networking contacts established during EU cluster meetings and EU initiatives. BONVOYAGE is actively pursuing liaison and clustering with projects working both on ICT/ICN and on transport related issues.

In the following sections we report about the positioning of BONVOYAGE within the ITS Connected Vehicles Cluster, its relationship with other relevant EU projects, and its contribution in the scope of the work programme.

2.6.1 *ITS Connected Vehicles Cluster*

BONVOYAGE is cooperating with other projects funded in the framework of the 2014 call H2020 (within Mobility for Growth) named ITS Connected Vehicles Cluster, and is part of the cluster itself. These projects created a so called ITS cluster that eases inter-projects cooperation in the ITS and connected vehicles domain. The objective of this cluster is to enhance project outcomes and results by joint activities, to enhance visibility of Connected ITS related projects, augment information flows between projects and their individual partners, foster clustered dissemination activities, with the goal of addressing a larger community.
Collaboration within the cluster includes workshops, regular meetings and conference calls, cluster working groups, data sharing and cross-reporting, development of promotional material. A joint cluster workshop was held in Brussels in November 2015.

BONVOYAGE is part of the cluster together with the following other projects:

- **CIMEC** - a city-focused project which will explore the role cooperative ITS systems (C-ITS) can play to support city authorities, both in managing their transport networks and the delivery of other transport-linked services. http://cimec-project.eu
- **CODECS** – Cooperative ITS Deployment Coordination Support, also involving the support of the Network of ITS National Associations. http://www.codecs-project.eu
- **ETC** – The European Travellers Club: Account-Based Travelling across the European Union is an initiative of several European e-Ticketing Schemes in Public Transport Members and the Open Ticketing Institute (OTI). The project aims to ensure that all travellers in Europe can use trusted, easy and seamless Account-Based Ticketing services, integrated with journey planning and travel information. http://54138954.swh.strato-hosting.eu/
- **EU Travel** – Optimodal European Travel Ecosystem. EU Travel attended the ITS Observatory User Requirements Workshop held in June 2015 in Brussels. The two projects will collaborate mainly in the framework of Dissemination activities and administration of surveys. Both projects will promote each other's events and activities. http://www.eutravelproject.eu/
- **HIGHTS** – High precision positioning for cooperative ITS applications. The goal of the project is to achieve high precision positioning system with the accuracy of 25cm in the area of Cooperative systems. http://hights.eu/
- **The ITS Observatory** is a 2 year support action which aims to develop a flexible and easy to use intelligent tool able to provide accessible and understandable information on Intelligent Transport Systems as developed and deployed in Europe. http://its-observatory.eu
- **MASAI** – Mobility based on aggregation of services and applications integration: http://masai.teleticketing.eu/

- **OPTIMUM** – Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility. The project is working to unveil state-of-the-art information technology solutions to improve transit, freight transportation and traffic connectivity throughout Europe. Through tailor-made applications, OPTIMUM is striving to bring proactive and problem-free mobility to modern transport systems by introducing and promoting interoperability, adaptability and dynamicity. http://www.optimumproject.eu
- **ROADART** – Research Alternative Diversity Aspects foR Trucks. http://www.roadart.eu/
- **SocialCar** – Open social transport network for urban approach to carpooling. The project aims to design, develop, test and roll out a service that simplifies the car-sharing experience of citizens in urban and peri-urban areas. http://socialcar-project.eu/about-project
- **TIMON** – Enhanced real time services for an optimized multimodal mobility relying on cooperative networks and open data. http://www.timon-project.eu/

Especially important is the concept of obtaining complementarity in development activities and implementations, so as to avoid overlaps, and try to focus effort on synergies, within the cluster. In line with this idea, BONVOYAGE already offered a preliminary solution of its Internames concept plus a Nation-level distributed Discovery Service software stack to other fellow projects belonging to the cluster.

The idea is that BONVOYAGE's networking technology can serve as the communication bus that all other projects of the cluster can try to utilize for their communication needs, and to interlink their data sources. BONVOYAGE proposed to use its solution to collect and share transport data among participant projects.

2.6.2 Related Projects

The BONVOYAGE platform relies on advanced methodologies, models and algorithms based on the previous experience of the partners in the Consortium and on the current state of the art, both in the Transport and in the ICT areas. BONVOYAGE has examined the architecture and outputs of the following projects and tools: FP7 PEACOX, FP7 OFELIA, MIT AutoEmotive, FP7 INTERSTRESS, FP7 CONVERGENCE, FP7 GREENICN, DYNAMO (a project within SINTEF's internal program), FP7 MOBINCITY, FP7 eCOMPASS, FP7 SMARTMUSEUM, FP7 FI-WARE, FP7 MOBINET, SMILE (a project funded by the Austrian Federal Government), FP7 Co-Cities, CIP Co-Gistics, NSF Named Data Networking (NDN), FP7 PURSUIT, NSF MobilityFirst, OpenTripPlanner (which is an open-source solution).

Out of these, taking into account the objectives of BONVOYAGE as well as the public availability of the related information, we have selected the most relevant subset of projects and tools whose architecture and functionality the Consortium believes to be particularly worth studying and analysing for the purpose of challenging BONVOYAGE to go beyond the state-of-the-art.

Such projects and tools are hereby listed:

- FP7 Co-Cities
- FP7 CONVERGENCE
- FP7 eCOMPASS
- FP7 MOBINCITY
- FP7 MOBiNET
- FP7 PEACOX
- FP7 SMARTMUSEUM
- OpenTripPlanner (open-source).

The study is reported in full detail in deliverable D2.2. Table 3 summarizes the results of the study. It is aimed at illustrating a synoptic view of BONVOYAGE and the above-mentioned projects, and clearly shows how, when we focus on a set of cutting-edge, innovative features, BONVOYAGE is able to build on top of the current state-of-the-art and innovate it. Thanks to a federated and modular architecture, all such features characterize our project. The features we refer to are the following: (1) capability to address large-scale transportation networks; (2) capability to manage multi-modal transport; the presence of (3) a user-profiling tool, (4) a multi-objective optimization tool, and (5) a tariff scheme tool; (6) personalized door-to-door multi-modal optimal trip planning of FEV in urban areas; (7) capability to manage passenger transport and (8) freight transport; (9) the presence of a feedback loop in the architecture; (10) privacy and security; (11) the presence of an information-centric network; (12) the interoperability among heterogeneous transport operators.

Conclusively, the study shows that BONVOYAGE is beyond the state of art as (i) it is the first project addressing simultaneously all of the above-mentioned problems, and (ii) it addresses them in a context of openness and federation.

Relevant Features	Co-Cities	CONVERGENCE	eCOMPASS	MOBINCITY	MOBiNET	PEACOX	SMARTMUSEUM	OTP	BONVOYAGE
Large-Scale Transportation Networks	✓	✗	✗	✗	✓	✗	✗	✗	✓
Multi-Modality	✓	✗	✓	✗	✗	✓	✗	✓	✓
User-Profiling Tool	✗	✗	✓	✗	✗	✓	✓	✗	✓
Multi-Objective Optimization Tool	✗	✗	✓ (just a route planner)	✗	✗	✓	✗	✓	✓
Tariff Scheme Tool	✗	✗	✗	✗	✓	✗	✗	✗	✓
Personalized Door-to-Door Optimal Trip Planning of FEV in Urban Areas	✗	✗	✗	✓	✗	✗	✗	✗	✓
Passenger Transport	✓	✗	✓	✓	✓	✓	✗	✓	✓
Freight Transport	✗	✗	✗	✗	✗	✗	✗	✗	✓
Feedback Loop	✓	✗	✗	✗	✗	✓	✗	✗	✓
Privacy and Security	✗	✓	✗	✗	✓	✗	✓	✗	✓
ICN	✗	✓	✗	✗	✓	✗	✗	✗	✓
Interoperability	✓	✗	✗	✗	✓	✗	✗	✗	✓

Table 3: Comparison with related projects

2.6.3 Contribution to Work Programme

According to the work programme, the project should address one or several of a list of 5 domains. The Table 4 below describes the contribution of the project to 4 of such domains, reporting first the description of each domain given in the work programme (in italic) and then the related BONVOYAGE contribution.

Table 4 is extracted from the proposal, and reports the contributions as planned. It is the one expected from the whole duration of the project. More detailed and current information about the project's progress beyond the state of the art in the first 18 months of work, as well as the project's innovation potential, can be found in deliverables D8.1, D8.3, D3.1 and D4.1.

Domain 1): *Interoperability and linking of the existing services, including necessary interfaces, in order to achieve the widest possible geographical and modal coverage to enable an open single European market for mobility services. The scope of the work should extend towards full-scale early take up and solutions should be tested on large scale.*

BONVOYAGE contribution

BONVOYAGE guarantees full interoperability among existing travel services offered by mobility operators (including, but not limited to those involved in the project) by defining and developing ad hoc interfaces, namely the Multimodal Integrated Interfaces, which are realized through a set of distributed agents transparently embedded in strategic ITC network nodes located on both the mobility operator and user side (e.g., generic nomad devices). Data exchanged among different mobility operators will be used to automatically identify multi modal, integrated and personalized travel solutions. To this end, the Internames Communication System will be conceived as an Information Centric Bus able to break the technological barriers that hinder seamless and secure network connectivity in the current host centric Internet design. Internames will ease interoperation among entities identified by names, without a static binding of end-points or users to their current location. In addition, Internames allows for travel requests and transportation plans to be temporally separated, with the seamless integration of query/response, facilitating search for suitable itineraries, and publish/subscribe functionality allowing users to post requests for travel that may be satisfied subsequently, based on demand-response planning by transportation operators.

In addition, BONVOYAGE will open a market opportunity to a sector that relies on micro and small transport carriers to offer their services to other companies and users. Within the project, this functionality will be tested for on road transport at urban and regional level, but could be extended to National and European level.

Domain 2): *Developing EU-wide common minimum standards for interoperable navigation and ticketing services, thereby facilitating regional solutions compatible with generic nomad devices (smart phones etc.).*

BONVOYAGE contribution

Both technological and commercial conditions will be investigated to make EU-wide common minimum standards for interoperable navigation and ticketing services possible. The starting point will be the development of two specific components in the BONVOYAGE platform.

The first is represented by Multimodal Integrated Interfaces that enable collecting basic information for interoperable navigation by means of web services accessed even by common smart phones. To this aim, Internames will provide name-based Application Programming Interfaces that accept names as identifiers of all requested content or services. By not having a static binding between the name of a communication entity and its current location, we allow entities to be mobile, enable them to be reached by any of a number of basic communication primitives, enable communication to span networks with different technologies and allow for disconnected operation.

The second component is a module dedicated to the tariff scheme, namely the Tariff Scheme Design Tool. It is in charge of identifying and making available to end users several multi-part tariff schemes based on bilateral or multilateral agreements in order to promote the joint use of a group of complementary mobility services. This tool will allow operators to propose data-driven joint offers for complementary intermodal transport services. Thus, behaviour-based discounts will promote a larger use of the socially desirable mobility services (e.g. those with lower CO_2 emissions). Moreover, real-time measured data and user profiles will be exploited to automatically compute suitable discounts which will be then promptly submitted to the travellers in order to attract them towards alternative and less congested travelling options. Therefore, traffic congestion peaks will be effectively mitigated thanks to interoperable navigation and ticketing services.

Domain 3): *Exploring more effective and more efficient cooperation and decision making mechanisms between stakeholders, including coordination of the existing European, national*

and regional initiatives, to foster EU-wide consolidation and deployment of high-quality integrated multimodal travel information, planning and ticketing services. This could encompass setting up a cooperation platform. **BONVOYAGE contribution** BONVOYAGE allows for cooperation and commercial agreements among different mobility service operators with the aim of: (i) offering a more suitable and personalized service in order to improve the quality of experience of their customers; (ii) getting the actual feedback from the customers with respect to the proposed travel solution. In particular, nowadays, user feedback is easily accessible by developing suitable 'apps' for nomadic devices. However, a key missing ingredient is a platform capable of analysing such feedback with respect to specific multimodal travel solutions and to model the degree of travel quality experienced by the users, especially when grouped together among a consistent set of user profiles. These weaknesses are fully tackled in BONVOYAGE thanks to the adoption of novel technology-independent Multi-Objective Optimization tools combined with the Tariff Scheme Design tool. The former will process system/ user feedbacks and profiles to maximize the quality of experience of travellers. The latter will provide a unified management of the possible disservices of the offered intermodal transport services. BONVOYAGE will also provide a cooperative tool for transport companies to hire delivery services among them and other users. This will allow them to better optimize the loads of each journey and therefore increasing profitability. Concurrently, this load optimization will reduce company's emissions, helping them to achieve CO_2 emissions targets, stated in 30% reduction by the EU for 2020.
Domain 4) (partially addressed): *Exploring mechanisms and structures for consensus building among stakeholders to foster EU-wide consolidation and deployment of cooperative ITS. This could encompass setting up a cooperation platform.* **BONVOYAGE contribution** One of the partners, MLC ITS Euskadi, is formed by a group of companies, governments and associations located in the Basque area (north of Spain and South of France). The mission of this Cluster is to achieve an integral competitiveness improvement in this region, through cooperation, innovation and interaction among all the agents and companies of the transport and logistics sector. Now the Cluster has 108 members grouped across five axes: 1. Operators, 2. Users or Chargers, 3. Products and Services for the sector, 4. Infrastructure owners or Managers 5. Administration and other Agents (Technology Centres, Universities, Chamber of Commerce, Authorities, Cities...). Even if the scope of the Basque Cluster is not Europe at large, such cluster will build awareness and consensus among different types of stakeholders, helping to devise best practises for cooperative ITS, to be adopted more widely. Access and management of data bases generated for the project will be based on agreements on regional terms and will remain as an asset after the project life to foster the transport sector in the region.

Table 4: Contribution to the Work programme

3 Creating the Vision

Creating a concrete instance of the vision we have depicted in the previous sections is the BONVOYAGE challenge. To this end, the project is designing, developing and testing a federated platform **optimizing multimodal transport**. The platform integrates travel information, planning and tariff services, by automatically analysing non-real-time data from heterogeneous databases (on road, railway and urban transport systems); real-time data (traffic, weather forecasts, data from smartphone and wearable sensors); user profiles; user feedback. The platform is supported by an **innovative communication network** that collects and distributes all the data required to optimize a travel.

In the following we will focus on a high-level description of the steps the project is taking towards the goal above.

Specifically, we first re-state the general objectives of the project as they are formulated in the Description-of-Work document, to keep in mind the original project's goal; then we include a set of four Reference Scenarios, which we imagined, that serve as benchmark for the capabilities of BONVOYAGE. We then describe the main components of the platform, in more technical terms, supporting our vision within the R&D state-of-the-art. Then we describe the market analysis that concretely supports our vision and its placement within the current, ever changing, business landscape of the ITS. Finally we examine the roadmap of the project as it unrolls in time and through milestones.

3.1 Project objectives

As a reference, we report in the following the specific technical goals, as stated in the original proposal, that the project seeks to achieve:

1. **Multi-objective optimization**. Development of an advanced multi-objective optimization algorithm to provide an optimal multi-modal travel itinerary by properly trading-off several simultaneous sub-objectives, namely travel schedule, travel duration, travel cost, travel emissions, overall travel reliability, load capability, type of goods, etc. This optimization is performed by simultaneously taking into account the following inputs: (i) non-real time characteristics (e.g., coverage, routes, schedules, type of good) of the candidate transportation means (e.g., public transport such as bus, train, boat, taxi, airplane; private transport such as car, bicycle, walking, cooperative modes like car-sharing, trucks), (ii) real-time requirements (e.g., traffic congestion, temporary road barriers, lane closures, temporary speed limits, new stops as a result of customers'

requests (not the same day but some days in advance), available space and weight to complete the load), (iii) user profiles and users feedback (see the "Personalization" issue below), (iv) dynamic tariff schemes (see the "Tariff scheme" issue below).

2. **Personalization.** Personalization of the services offered by the platform, aimed to meet, as far as possible, specific user preferences, needs and expectations in terms of travel schedule, travel duration, travel cost, transport means, travel reliability, etc. Personalization is performed, on the one hand, on the basis of an automatic mapping of each user to the most appropriate user profile corresponding to given parameters which are used in the framework of the optimization mentioned, and, on the other hand, on the basis of the automatic interpretation of the feedback provided by each user, as well as by users belonging to the same profile. This enables operators to have 'demand-response' systems where, based on the needs of a dynamic grouping of users with common profiles, transportation facilities may be dynamically created to meet demand. A further objective lies in the identification of the user profiles in a data-driven fashion through appropriate machine learning techniques.
3. **Tariff Schemes.** Design of a tool aimed at providing tariff schemes which, on the one hand, encourage the use of specific classes of mobility and delivery services (e.g., those with a lower environmental impact, type of good), and, on the other hand, create new business opportunities for the transport operators, which can offer special prices for multimodal travel allowing them to increase the exploitation of their transport resources. The goal is to integrate the tariff scheme tool in the multi-objective optimization framework, possibly allowing dynamic changes and re-negotiations during the trip. For freight delivery services, the BONVOYAGE platform can be a perfect complement to the existing pricing services with extended and more flexible features such as real-time pricing or allowing a dynamic matchmaking between users' needs and company's offers.
4. **Interoperability.** Natural and simple interoperation among heterogeneous transport operators. The interoperation is designed to be technology-independent, so that it can work with any transport operator, regardless of the technology the operator adopts for data acquisition/storage, the database organization or its data format. As a matter of fact, the above-mentioned functionalities deal with homogeneous metadata obtained by appropriately converting the heterogeneous data of different, individual transport operators. On the other hand, only a few trivial functionalities are technology-dependent and have to be developed "ad hoc" for each transport operator; these are the functionalities related to the interfacing with the users and conversion of the heterogeneous data of the individual transport operators; they are implemented by means of distributed agents transparently embedded in users' smart cellular devices and in suitably selected nodes of the transport operators, respectively.
5. **Internames Communication System.** A pivotal feature in BONVOYAGE consists of an Information-Centric Network (ICN) that fulfils the communication requirements entailed

by the aforementioned objectives by providing (i) seamless connectivity across different existing network realms (that may be administered by distinct transport operators or authorities); (ii) native support of mobility and security issues; (iii) travel-centric primitives for push/pull based services; (iv) high efficiency in communication and processing operations; (v) graceful deployability and interoperability with existing and upcoming networking systems (i.e., 5G and beyond). As anticipated in the background information box above, the highly heterogeneous, distributed and mobile nature of the data of interest, coming from data-centres, sensors, vehicles, goods and people on the move, calls for a network that is able to go beyond current paradigms. Our network, called Internames, (better described in the following) allows name-to-name communication, without a static binding of end-points or users to their current location; in Internames names are used to identify all entities involved in communication: content, users, devices, logical points, and services. For instance, a sensor providing traffic information is identified by a name; a traveller is identified by a name; a database content is identified by a name; train, buses, cars, bicycles, planes, are identified by names; a transport service and an itinerary are identified by a name. All communications among such entities happen between names; it is the task of Internames to locate where such entities are located at a given time and to map name to location in a dynamic, context-dependent way, and to map a name not only to a current location but also to a protocol/service/communication type. In addition, the Internames architecture allows for requests from users to be treated as a subscription that is maintained in the network, so that e.g. when an itinerary at an appropriate tariff becomes available, meeting the requirements of the user (e.g., schedule including data and time of travel, quality of experience etc.), the network may then notify the user. This allows for dynamic 'matchmaking' between users (people, goods) wishing to travel from a starting point to a destination and the (potentially dynamically) demand-response based scheduled transport of selected groups of transport/mobility operators. Our aim in BONVOYAGE will be to continue the design of Internames, now at the very beginning and to exploit/adapt it to our transportation system.

6. **Security and privacy.** User profiles are certainly very useful (one could say needed) to program and optimize travels; however they imply an obvious threat to the privacy of users, who will be reluctant to use the platform if they are not sure that their preferences and choices will not be protected and kept private. In addition, security of all transactions in the BONVOYAGE platform (including payments) is of course a key requirement. These issues, well understood and addressed in traditional networks, require a significant rethinking when challenged against the unique distinguishing characteristics of ICNs and of our envisaged transport scenario. Traditional network security protocols, such as IPsec or Transport Layer Security (TLS), focus on protecting the communication between an information consumer and a content server, and do this by deploying trustworthy

infrastructures devised to enforce authentication and access control primitives on dedicated servers. In our ICN network, the requested content is not necessarily associated to a trusted server or an endpoint location, but it can be retrieved from, say, a network cache managed by a hardly trusted administrative domain or by a sensor or by a user device. This calls for data-centric, infrastructure-less security and privacy solutions, being hardly viable a secure infrastructure that involves storage servers and network caches in heterogeneous non-collaborative domains. Access requests are addressed to a named content, and thus cannot be protected into an encrypted tunnel or TLS connection towards a server address, or through an off-the-shelf anonymization mix network such as TOR. Thus, we will investigate data-centric techniques, where security and privacy rely on information exclusively contained in the message itself, or, if extra information provided by trusted entities is needed, this should be gathered through offline, asynchronous, and non-interactive communication, rather than from an explicit online interactive handshake with trusted servers. The ability to guarantee security without any online entity is particularly important in the fragmented network scenarios tackled by BONVOYAGE, where mobility may technically preclude the ability to connect to a remote trusted party. As matter of fact, protecting information at the source, by embedding security information in the content, is more flexible and robust than delegating this function to applications, or securing only the communications channels. For instance, data gathered by a sensor or coming from a user device, encrypted at the source, can travel over unsecure channels, and can be decrypted only by the intended receiver.

3.2 Reference Scenarios

All scenarios show most of the key innovations of BONVOYAGE, each to different degrees and under different viewing angles, so as to demonstrate that such key innovations are the building blocks of any modern ITS.

Key innovations:

- User profiling to assist the transport system at planning phase
- Real-time sensors and dynamic data assist the transport system at travel phase
- Name-based networking to assist transport operators and developers in exchanging and searching data
- Constraint-based optimization of the proposed solutions
- Distributed approach to scale continent-wide
- Design grounded on inter-modality

3.2.1 Scenario 1: Family travels from Oslo to Italy for tourism

The first scenario is about **inter-modal planning in the context of public transport**, and shows how BONVOYAGE:

- Scales up to continent wide trip planning.
- Is effective at selecting the optimal combination in case of groups in need of special care.
- Can provide users with real-time information on public transport status.
- Can re-plan by taking into account dynamic conditions.
- Exploits user-profile and constraints to formulate a tailored solution (tourism with several stops, plan for events in the area, reserve for strollers and heavy luggage, budget constraints and personalized tariffs).
- Enables users to purchase a multi-modal travel solution as well as leisure services (e.g. museum tickets).
- Enables users to subscribe to a fidelity programme and collect scores to be used to get awards.
- Enables users to fix a “mission” to be achieved during the journey.
- Allows users to share and suggest their travel itinerary to other BONVOYAGE users.
- Allows transport operators to offer promotions to users.

The family travels from Oslo to Italy for tourism, and kids need the stroller. They want to tour Northern Italy (Milan, Firenze, Pisa) and attend a specific paint exhibition in **Rome at a fixed date**. The exhibition is managed by the “Museum of Contemporary Art”, which has a partnership with one of the transport operators associated to BONVOYAGE.

Family has booked and purchased public transport tickets and museum tickets through BONVOYAGE. They are member of BONVOYAGE fidelity programmes and gain 400 scores when purchasing the cross-border multi-modal travel solution. They have reserved hotels in Milan, Firenze and Rome that are very close to the train stations, so that they can walk there.

Once at home, they share and recommend their travel itinerary to other BONVOYAGE users with a similar “families with children” profile.

At the end of the journey, family receives promotions/discounts from the partners of BONVOYAGE on similar events/travels, based on travel solution they eventually enjoyed, the specificities of their “family” profile and the estimated CO2 consumption.

3.2.2 Scenario 2: Business trip from Grenoble to Bilbao

The second scenario is about **inter-modal planning between traveling with private car, shared cars and public transport**, and shows how the private transports can seamlessly blend with the public ones, when assisted by sensors and real-time data.

This scenario focuses on:

- Receiving and processing data from sensors, either deployed on the road or from users’ mobile devices.
- Conveying timely alerts to users, about incidents and dynamic events, which influence the plan.
- Inter-modal optimization of resources by car-pooling, both in a multiple-sources-one-destination and in a one-source-multiple-destinations cases.

Cristelle, a researcher from Grenoble needs to attend a meeting in Bilbao. Her user profile in BONVOYAGE is a “business” profile and she is usually happy with driving her private car as much as possible. BONVOYAGE originally offers the fastest solution, and the driver is planning to reach Lyon airport by car and then fly to Bilbao.

During the trip, say when Cristelle is collecting her luggage at the airport, she is notified that another passenger, who either was on the same flight or has got to Bilbao at the same arrival time, is going to a destination that happens to be in the same urban macro-area of the conference she will attend. Cristelle accepts to pick new person up in the previously-reserved shared car. BONVOYAGE consequently makes a local trip planning update matching the needs of the two passengers.

3.2.3 Scenario 3: International freight transport from Bilbao

The third scenario is about ability of BONVOYAGE to exploit exogenous constraints in the **ranking of optimal a long-range travel solution**. It showcases the planning of a freight delivery on an international transit route that spans from Bilbao to Oslo.

End users in this scenario are big transport companies who plan freight services by passing to the system all the needed information (i.e. origin, destination, weight and other preferences and needs such as: refrigerator, dangerous, time constrains, etc.) and small transport companies (often one-man size) that offer freight transport services and publish available information on BONVOYAGE.

Scenario involves optimization of the travel solutions, from the point of view of the transport operator, based on:

- Contractual (Transport operator & client) Factors: freight characteristics; time delivery;
- External factors: traffic regulation of countries; real time events (traffic, accidents).

Transport operator is informed, by means of trusted communications that guarantee un-tampered and certified notifications, of the real route followed by the driver, occurred incidents (if any) and the confirmation of the delivery.

In a sense, Scenario 1, Scenario 2 and Scenario 3 complement each other and demonstrate that the future ITSs are asked to support a customer-friendly blend of public and private transport, for increased sustainability, ability to absorb peaks in service utilizations and optimal coverage of the territory.

3.2.4 Scenario 4: Exploiting the platform from outside

The fourth scenario demonstrates that BONVOYAGE is **conceived as an open platform** and that interfaces with data sources are based on an innovative networking that collects and distributes, where needed, data as soon as they are published. This facilitates both transport operators and developers of added-value applications that exploit the BONVOYAGE platform, and creates new business opportunities, opposing the centralized, one-player-solves-it-all tendency.

Context

Expedia has become the world's biggest travel agent, *The Economist* reports. The third-largest travel agent is also an online company: Priceline. The scale of Expedia and Priceline means they can negotiate better prices, than their smaller rivals. Google Maps has quickly become one of the widest journey planning apps on the market. The smaller online travel operators find it increasingly hard to compete with the big ones.

Emerging small travel operators would like to offer advanced transport services at regional, city or private scales in order to increase their market share and visibility.

- *Regional scale*
  A travel agent with an extended and well-established network of partner hotels and resorts wants to propose to vacationers a set of tours made available by heterogeneous transport operators.
- *City scale*
  A company would like to be able to contact parking lots owners and be informed about their availability without having to (i) establish many different business relationships, (ii) deal with different data formats, and (iii) constantly polling the external servers.
- *Private scale*
  Often, when major sporting events or concerts take place, public transportation goes overloaded and people prefer resorting to private cars or try to organize parallel, private-owned buses and shuttles. A smart App developer would like to create software that collects info about people offering their own vehicle with free seats, for short periods, and on a very specific area or itinerary, but realizes this is a complex goal to accomplish because, unfortunately, today technologies are not able to effectively offer user-to-user vehicle-sharing services.

Despite their valuable proposals, such small entrepreneurs travel operators may incur in serious difficulties in offering their services. They, instead, would like to get rid of technical burdens that impede a fair competition, as everyone would benefit from an **ecosystem of competing online travel operators**. Major obstacles are the difficult inter-operability with official journey planning services (like the Municipality public bus service), absence of inter-operability with other similar services that would provide wider and multimodal coverage, and the amount of investments required to design (and set up) a centralized server holding the required information in a secured way.

With BONVOYAGE, the three above business initiatives are fully supported.

Concluding remarks on Scenarios

More in general, all four Scenarios presented above are supported because BONVOYAGE is designed from grounds up as a distributed system able to:

- Exploit and nurture **local specificities** of the various transport systems available in the area.
- Facilitate large-scale integration, **search, sharing and delivery** of transport solutions and related data among transport providers, travel service operators, applications and users; this is one of the main problems nowadays: how to collect transport information not only from big airlines/train operators but also from all the millions, small scale, bus/local transport/private providers.
- Allow transport providers to **keep their data and services in their premises**, with their formats and interfaces, rather than transfer them to a third, centralized party (e.g. Google) and/or to comply with specific format (e.g. GTFS).
- Allow travel operators or applications to **get data directly from the transport providers rather than from a third party**.
- Allow anyone to easily publish transport solutions, **including private citizens** (e.g. for car sharing purposes, hitching a lift).
- Allow anyone to set **up access restriction and privacy policies** on published data and then verify the owner and the authenticity of published data.
- Allow anyone to easily exploit all such information (e.g. **anyone can develop** an application and become an online travel platform provider).

3.3 The BONVOYAGE Platform

BONVOYAGE focuses on the design of an architecture based on **three main system components**: i) **applications**, which must cope with dynamic, distributed, multiparty, open scenarios. Applications guarantee that travel instructions are personalized for each user, and adapted in real time to current transport conditions of a given context; ii) **a federation of data and travel planning services** that provide multimodal and optimal travel solutions, which are in turn orchestrated for that user and that context; iii) a **communication system**, which provides large scale delivery of all relevant data, from schedules to sensor-generated and user generated real-time information.

Together, these components form the BONVOYAGE platform.

In the following, we describe in more details each of these components, trying to summarize their more innovative/appealing characteristics. The reader should refer to deliverable D2.2 for the full details of the design of the platform.

3.3.1 Applications

Applications (mobile clients + their application servers) allow users to seamlessly interact with BONVOYAGE.

The main BONVOYAGE application server offers **personalisation and orchestration services**. It relies on a database of user-centric data, which is dynamically collected through the mobile clients that interact with end users. The user’s behaviour and feedback data are used to derive data-driven user profiles that are used to customize services and travel solutions. The orchestration service acts as a distributed route planner component, and exposes interfaces for invoking route-planning functionalities.

The main BONVOYAGE mobile client **provides route information to the user and collects relevant user feedback** while she is traveling, feeding the personalisation and participatory sensing services of the application server. It enables users to find the best way to go from one place to another taking into account the users personal needs and preferences in terms of schedule, duration, costs, transport means, reliability, transport mode related to low user's stress level, etc. The application follows an interactive design allowing users to intuitively request required information and receiving personalized multimodal travel routes. During the trip, the application guides the user with required information and reacts on dynamic, real-time conditions that interrupt and affect the on-going trip. Users' feedback, including feedback coming through smart wearable sensors, gets collected via both unattended and attended apps running on the client.

3.3.2 Federation of Data and Travel Planning Services

Optimal Routing Algorithms

The travel optimizer is a core function of the BONVOYAGE platform. Our solution is a collaborative framework for federated optimization services. This approach enables the necessary scalability to handle continent-wide travel networks combined with personalized travel preferences. At the same time, it also enables fast response to real-time events. Hence, the resulting solutions are truly intermodal, handling combinations of any private and public modality in the same journey. The existing, alternative technology heavily relies on extensive pre-processing, which limits the possibility to exploit real-time information as well as personalized user profiles. The BONVOYAGE travel optimizer goes beyond these limitations thanks to its federated architecture and its novel algorithms.

The federation contains a collection of different route optimization algorithms, operating at different level of aggregation and detail. To be able to provide routes based on the real-time situation, each route planning algorithm is continuously updated with new projected travel time estimates, delays and other incidences relevant to the geographical area and the modalities that the algorithms covers.

The service is triggered by route request containing user data collected from the database of user-centric data and provides intermodal routes optimized according to the request, the personalized user profile and the real-time situation. To be able to scale the service into a continent-wide route planner the federation is implemented by means of multiple access points distributed over the territory. Each access point makes use of the orchestrator that is in charge of decomposition the request, and distributes the sub-requests to appropriate solution algorithms.

Data Discovery

The data Discovery Service, which we call OpenGeoBase, is the decentralized large-scale storage system used for building quite generic georeferenced services within the platform. OpenGeoBase exploits Internames to collect and make available georeferenced transport-related data. Basically, OpenGeoBase allows anyone to publish data relevant to a specific geographic area, ranging from transport schedules to sensor-generated or user generated real-time information, but also, point of interests, etc. Then, interested users/travel operators can search and retrieve all data available in such geographic area, which are needed to plan an optimal multimodal trip. Publishers are not forced to upload their data in a central repository but they can keep them in local, distributed repositories, under their control. OpenGeoBase logically puts together all individual repositories and make it easy for users to search for and retrieve the data they are interested in. We call *slice* a space in a set of Repositories and *tenants* the application owners (e.g. journey planners) that can rent a slice for their applications. Users of a tenant can Create, Read, Update and Delete data on tenant repositories. The database can grow without bounds by merely deploying new servers (horizontal scalability), and Internames takes care of routing the queries towards the best servers and cache the answers to popular queries to speed-up response time. By exploiting Internames's in-network multicasting and caching, massive information describing routes, prices, schedule plan, etc. can be quickly provided to millions of users, also under flash crowd conditions and severe events, such as interruption of a major road, extreme weather, disaster. By exploiting Internames security, the database can secure every piece of information in a customizable way and can include configurable policies as to who and when and where can access the information. As a result, OpenGeoBase is: i) distributed, not requiring a centralized entity, ii) scalable, capable of growing without bounds; iii) secure, every piece of content can be secured in a customizable way and can include configurable policies as to who and when and where can access the information; iv) slice-able, several tenants and users can use it in parallel and independently; v) reliable: no single point of failure; vi) fast.

So far, we have indexed all Google public GTFS files in our OpenGeoBase db.

Data is fetched from http://www.gtfs-data-exchange.com and then indexed by using an OpenGeoBase slice.

Discovery is quick in small areas of about 1000/2000 km^2. We are now trying to speed up also larger selections, e.g. all Italy or even better all Europe. The distributed database has 7 millions of entries and indexes about 1000 GTFS files.

A preliminary version of this integrated GTFS sources indexing effort is available at http://BONVOYAGE2020.eu/travelcentricservices.

Data is offered through a REST interface, which is better documented in the "Internal interfacing architecture" chapter, as a specific software component API.

3.3.3 Communication System

Even if ICN is posing the foundation of the Future Internet, it is widely accepted that it is impossible to reach a worldwide network architecture completely based on ICN in upcoming years. Only few portions of the network could be really re-designed from scratch, thus integrating pure ICN communication principles (clean-state solution). Nevertheless, to push the evolution of the Internet towards the information-centric approach, ICN could be quickly deployed as an overlay network, i.e., on top of the existing IP protocol suite.

Many other pieces of the current Internet architecture will still use the conventional IP protocol. The resulting network architecture is extremely **heterogeneous**. Embracing this heterogeneity is fundamental to BONVOYAGE, given its federated and large-scale nature of mobile transport data, coming from data-centres, sensors, vehicles, goods and people on the move. We cope with heterogeneity aspects by, on the one hand, grouping network nodes in clusters, simply referred to as **realms**, where data delivering is handled by means of specific communication protocols. On the other hand, network realms will be connected to each other through dedicated border routers, thus requiring advanced internet-working solutions.

Starting from these premises, the BONVOYAGE Communication System has been conceived in order to target:

- the design of a **scalable communication protocol based on the ICN principles**, able to easily support the exchange of travel-centric and sensing contents across multiple domains;
- the simplified provisioning of **request-response and publish-subscribe communication schemes** on top of the aforementioned heterogeneous network, while ensuring a complete interoperability among different technologies and applications; Request-response and publish-subscribe communication schemes are the main mechanisms through which applications may fetch contents from the network. With the request-response scheme, data are retrieved synchronously: every time a journey planner application would fetch that content, it has to send a request towards an external source of information, which will immediately provide the corresponding answer. The publish-subscribe communication model, instead, is based on an asynchronous interaction. In that case, the journey planner application issues a subscription request for a given

content of interest. Then, every time a new content is generated, the external source of information is in charge of delivering that data to all the subscribed applications.
- the development of a **scalable name-space** which uniquely identifies travel-centric information, sensing data, data consumers, data producers, and any operation handled at both application and network layers.

Internames, a specific instance of ICN, is purposely designed to support name-based communications across heterogeneous domains and data exchange in this multi-domain environment. Indeed, Internames evolves from the baseline ICN **host-to-name** principle to a **name-to-name** principle.

Moreover Internames can identify not only contents, but all entities involved in the communication, without requiring a statically bound to a physical location: source/destination entities and services are included. Specifically, in Internames, all elements involved in the network (including contents, services, users, and devices) are identified by names.

Additionally, dedicated logical nodes are **disseminated in the network** in order to offer search engines, message routing across realms, and publish-subscribe functionalities.

To support data dissemination in a way that is transparent from the underlying communication technology and that guarantees a standardized interaction among different applications, a powerful middleware layer, namely **Internames Service Layer**, is deployed on top of the network layer. In particular, any device involved in the communication, like data consumers, data producers, border routers, and logical nodes implements an instance of the Internames Service Layer that (i) exposes a set of standardized API for requesting, subscribing, and publishing contents to the application layer and (ii) hides all the operations executed at the network layer when triggered by aforementioned API.

A hierarchical name-space has been designed in BONVOYAGE, to identify contents, users, border routers, and Internames logical nodes, as well as any operations triggered at the network layer by the aforementioned Internames API.

Note that the entire BONVOYAGE platform jointly exploits Internames, the middleware layer and the name-space for efficiently offering request-response and publish-subscribe communication mechanisms on top of heterogeneous network architecture.

Internames offers search engines, message routing across realms, and publish-subscribe functionalities through three logical nodes: **Object Resolution Service (ORS)**, **Name Resolution Service (NRS)**, and **Internames Rendezvous Node (IRN)**. They are used to execute three different high-level functionalities offered at the network layer, as follows.

Object Resolution Service offers a mapping functionality and plays the role of a search engine. In general, a data consumer that is interested to retrieve a given content could not know a priori the name that the BONVOYAGE platform uses to uniquely identify it. Therefore, it sends to the ORS node a message containing a set of meta-data. The ORS will answer with a message reporting the list of names that map the aforementioned meta-data. ORS functionality is crucial to the concept of federation and synergic to Data Discovery (see above).

Name Resolution Service handles routing operations within the heterogeneous network infrastructure. By knowing the distribution of data providers, it finds the best routing path through which forwarding the requests generated by data consumers. NRS is contacted by the data consumer or by other routers along the path every time a request should be sent towards a new network realm. This routing functionality receives as input the name of the content to be retrieved and returns as output the next hop of the path and the related network protocol to use.

Internames Rendezvous Node manages publish-subscribe functionalities. Hence, it tracks the set of contents available in the BONVOYAGE platform, processes the submission requests, and notifies subscribed data consumers every time a new content of interest is available.

3.4 Technical Structuring of the Project

The following Figure 3 shows BONVOYAGE's functional architecture and its relationship with Work Packages from a high-level point of view, and draws a technical perimeter for the project, which holds unchanged from the proposal document. Nonetheless, the *interpretation* of the functional architecture of Figure 3 has obviously progressed in this first half of the project's lifespan. We have now come to a precise understanding of the overall implementation strategy for the project, as reported in the above sections, so that we are now able to understand how the functions depicted in Figure 3 are implemented by the devices depicted in the context of the federated architecture (Figure 2, above).

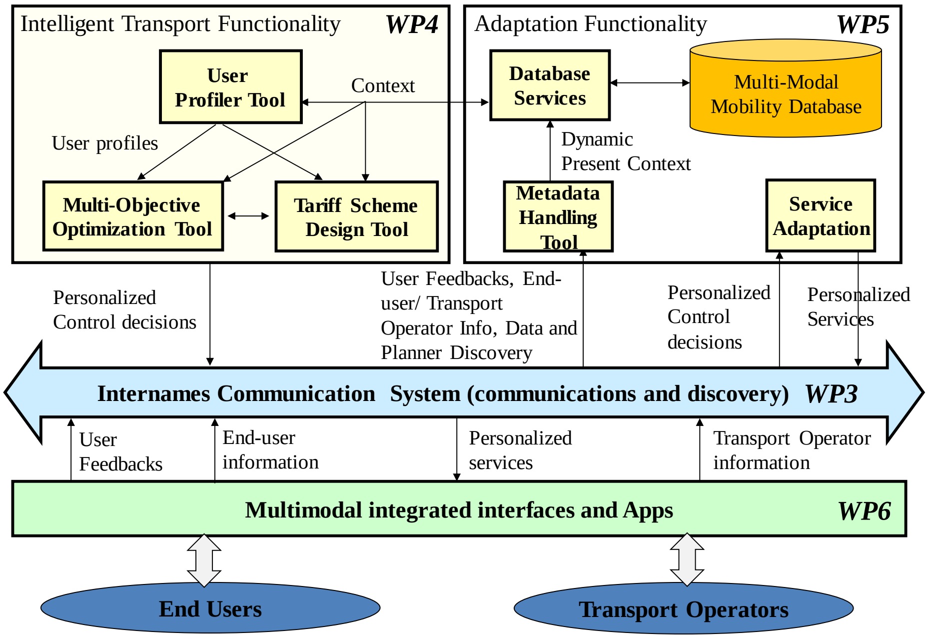


Figure 3: BONVOYAGE high–level functional architecture and relationship with Work Packages

Specifically, the BONVOYAGE federated architecture makes it possible to discover and exploit services offered by a distributed set of planners, which are provided by BONVOYAGE, but also by any other external project or stakeholder.

BONVOYAGE devises key proof-of-concept planners and an orchestrator, demonstrating the feasibility of the federation. They are collectively developed by WP4 and WP5.

WP4 designs individual planners' logic and the orchestration function within the general framework of the *Multi-Objective Optimization Tool* (MOT), and the personalization function within the *User Profiler Tool* (UPT). Planners can use information related to the user coming from the UPT to better adapt the solution to the user preferences. Planners can also use tariff schemes implemented through the *Tariff Scheme Design Tool* to compute the cost of the possible solutions, and these tariff schemes can be function of both the user profile and the travel solution, thus fostering energy-saving (green) solutions.

In order to tackle the complex computational task involved with a real-time multimodal multi-objective route planner at continental level, BONVOYAGE develops a novel hierarchical, **decomposition-based approach, the Orchestrator**. It is a decomposition approach to solve the routing problem on a multimodal network N that may be viewed as a pair (*N*,*A*), where *N* is a multi-modal network, and *A* is an algorithm to find an optimal route (for a class of objective functions) between any origin/destination pair within *N*. To perform its task, the orchestrator relies on a set of solvers A_1, …, A_q to compute an optimal route in a corresponding multi- or single-mode sub-network N_1, …, N_q with the property that $N_1 \cup \ldots \cup N_q = N$. Depending on the specific query, the orchestrator will pick up a suitable subset of solvers, run them, collect the partial solutions and compose them into a unique one answering the original query. Please notice that what we have loosely indicated, interchangeably, as planner, planner logic, journey planner service, or route optimization algorithms, is precisely defined in the context of deliverable D4.1 **with the term *Soloist***, which nicely matches the concept of an orchestra director orchestrating the soloists in order to perform a symphony**.** Briefly, **a pair (N_i, A_i) is a soloist, i.e. a match of a sub-network and a solver algorithm**. This is illustrated in Figure 4.

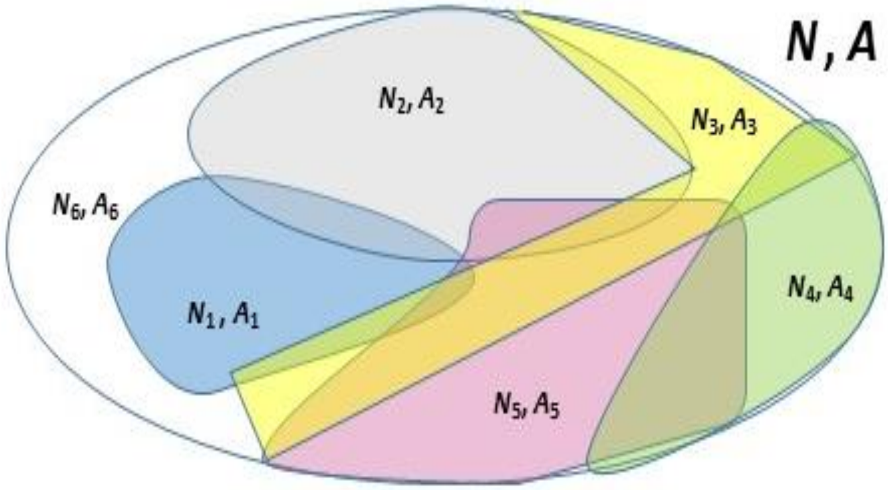


Figure 4: Soloists and Orchestrator of a multimodal network

WP5 takes care of collecting all the information necessary to all WP4 tools through a *Metadata Handling Tool*, which also takes care of publishing information, making the specific planner/soloist discoverable and retrieving information about the availability of other planners/soloists within the federation. All information is stored in a local database (*Multimodal-Mobility Database*, accessed through the *Database Services*). In addition, WP5 includes a *Service Adaptation* functionality that takes as input the travel plans derived by the MOT (namely, *Personalized Control Decision*) and sends them to the user *Apps*, changing them to a format properly adapted to the user device and context (*Personalized Service*).

WP6 takes care of designing and implementing some exemplary mobile Applications, and related interfaces, that use the federated architecture and the "official" BONVOYAGE planners/soloists, through which a user can interact with the system.

WP3 develops the *Internames Communication System* (ICS), together with specific travel-centric data services, such as the discovery service OpenGeoBase (OGB). Most of the communication between modules exploits ICS, which offers name-based request-response and publish-subscribe services at scale. It can be simply considered as a communication middleware, which simplifies the developing since it makes possible to use names rather than IP address, provides native mobility support, handles security and privacy, efficiently distributes large set of contents exploiting internal multicasting and caching functionality. OGB is an Internames-based spatial federated database, which is used to support the discovery services of the federated architecture at large.

3.5 Market Analysis

The definition of the BONVOYAGE potential market relies upon the scoping of the overall European digital mobility services market, and upon identification of specific users groups composing this market.

European demand for transport is continuously increasing: Europeans travel around 35,000 passenger kilometres per year; a European citizen makes about 923 trips per year or 2½ trips each day. Nowadays, most of these are still made by car (64%)[4].

Nevertheless, a relevant change is taking place concerning citizens' usage and preferences of transport modes. The use of public transports has increased steadily increased in Europe since 2002 and, more importantly, Europe is becoming a primary hub for the public transport sector innovation.

In this context, it is necessary to take into account on-going and future disruptive changes driven by the digitisation in the transport sector overall. Digital technologies are causing a relevant impact on:

- the way citizens travel and make their mobility decisions;
- how transport operators provide and manage their services.

In the first case, citizens are becoming more demanding about their travel experience and their expectations on transport operators' reliability and services, due to: the increased availability and access to more travel options; the possibility to get real time information on transport and traffic status as well as to compare a multitude of travel solutions with a full set of information (e.g. price, travel duration), empowering them to make more informed mobility choices.

To provide a concrete example, at urban level, citizens expect public services to be easily accessible and highly reliable to be preferred to the private car. Also, in case of disruption, users expect to find quick wins solutions to timely complete their travel itineraries, with no major

[4] Deloitte, Transport in the Digital Age. Disruptive Trends for Smart Mobility, March 2015.

difficulties. Consequently, users are acquiring an increasing influence on the services offered and business models adopted by transport operators.

In the second case, transport operators shall increase their ability to dynamically and rapidly adapt their services to meet new travellers demands. Thus, the main challenge for transport operators is not to modify travellers' behaviour but to timely follow, accommodate and even anticipate it. They shall provide a wide range of choices targeted and differentiated to the several types of travellers, ranging from urban or inter-urban commuters to business travellers and ageing people. In this regards, the integration among different transport modes (including train, bus, subway and "new" form of transports like car sharing and bike sharing) is a key element to ease mobility at local, national and cross-border level, ensuring seamless and smooth transition from one mode to the next. For this purpose, the interconnection and integration of technologies and data is necessary and serves as a building block for the creation of an intelligent transport system, bringing together private and public transport operators and institutional stakeholders, able to ensure real response to travellers demand, external events and "assist" travellers in case of disruption.

Furthermore, payments digitisation is paving the way to the possibility for transport operators to define new, profitable models. For instance, digital payment can support new ways to charge travellers, combining their journey origin-destination request and other factors such as time of the day, class of travel, discounts, previous travel patterns and other traveller specific data.

Based on the picture described above, it can be concluded that BONVOYAGE potential market is composed of two main groups of users:

- citizens travelling at local, national and cross-border level as primary users;
- transport operators needing to satisfy citizens new demand as secondary users.

As a matter of fact, BONVOYAGE platform will be able to provide users an innovative and comprehensive mobility service and an enriched travel experience, giving them the possibility to:

- find the best door-to-door travel solution for their journey itinerary;
- receive personalised travel solutions, based on their profile, preferences and past mobility behaviours;
- receive real time information on transport modes and traffic status;
- get assistance in case of disruption.

Thus, BONVOYAGE platform will be able to meet "digital travellers" new needs and expectations for mobility services, also accommodating different users profiles, characteristics and needs.

Concerning transport operators, BONVOYAGE platform will provide them:

- a concrete mean to leverage on the potential and the opportunities offered by digital technologies in the transport sector;

- an additional and relevant cannel to convey their transport services to a wider range of users, with positive impact on their business and revenues;
- offer their customers an enriched and exhaustive travel experience, thus increasing their attractiveness and customers loyalty;
- integrate their services with other transport modes in multi-modal travel itineraries.

Therefore, BONVOYAGE platform will be able to support transport operators in keep pace with the digital transformation in the transport sector as well as to support their business objectives, providing them the possibility to reach an increased number of customers and/or providing new revenue streams.

3.5.1 Market Study

A market study was carried out in order to identify the current state of art and the different functionalities and features of the existing widely used mobility and travel platforms and Apps at national and European level. The study investigated different platforms and Apps:

- 3 Travel Platforms, including a commercial one developed by BONVOYAGE project partner Trenitalia (PICO);
- 11 Local Public Transport solutions across EU Member States and third countries.
- 15 Journey Planners/Travel Apps

In this section a description of the market study objectives, methodology and main findings is reported, with the aim to describe the journey planners' and travel apps' so called *"AS – IS Scenario"* (i.e. the present situation, as it currently is) and identify the main differences between them and BONVOYAGE platform, highlighting innovation coming from BONVOYAGE and the added value brought to the market (which we call the *"TO – BE Scenario"*).

By going through deliverable D8.3 the reader can retrieve full details of the market study. **Synthetic observations about the market are here reported, though, because they are integral to the BONVOYAGE vision and its consolidation among partners.**

The main goal of the market study is:

- The identification and description of the main strengths and weaknesses of the existing journey planners and travel apps, in order to identify the missing features and functionalities;
- The identification of the most appropriate positioning of the BONVOYAGE platform in the market.

The benchmark study was developed on a conspicuous number of multi-modal journey planners and travel platforms in order to identify the best solutions currently available on the market.

The platforms and Apps that were analysed are reported in the following Table 5.

N.	Product	Category	Country	Link
1.	Trenitalia Commercial Platform (PICO)	Travel (purchase) platform	Italy	http://www.trenitalia.com/tcom-en
2.	Bpass Lignes d'Azur App (France)	Local Public Transport solution	France	http://www.lignesdazur.com/index.asp
3.	Lyon Optimod initiative (France)	Local Public Transport solution	France	http://www.optimodlyon.com/en/accueil/actions
4.	Técély Card & City Card (Lyon, France)	Local Public Transport solution	France	https://theworklife.com/experience/how-to-buy-a-carte-tecely-in-lyon/ https://www.lyoncitycard.com/?lang=2
5.	Stockholm Access-kortet (Sweden)	Local Public Transport solution	Sweden	http://sl.se/sv/info/biljetter/sl-access/kopa-biljett/
6.	Dutch OV-chipkaart (The Netherlands)	Local Public Transport solution	Netherlands	https://www.ov-chipkaart.nl/home-1.htm
7.	London Oyster Card (United Kingdom)	Local Public Transport solution	United Kingdom	https://tfl.gov.uk/travel-information/visiting-london/visitor-oyster-card
8.	Masabi solution (United Kingdom)	Local Public Transport solution	United Kingdom	http://www.masabi.com/about/
9.	Rio Card (Brazil)	Local Public Transport solution	Brazil	https://www.cartaoriocard.com.br/rcc/institucional
10.	Beijing Yikatong Card (China)	Local Public Transport solution	China	http://www.beijingholiday.com/beijing-travel-tips/beijing-yikatong.html
11.	Singapore EZ-linked card (Singapore)	Local Public Transport solution	Singapore	http://www.ezlink.com.sg/
12.	Trenitalia App	Journey planner	Italy	http://www.trenitalia.com/tcom-en/Purchase/Mobile-Ticketing
13.	Smile / Beam Beta (developed by Fluidtime)	Journey planner	Austria	https://www.fluidtime.com/en/about-us/references/beambeta http://www.wienermodellregion.at/das-projekt/massnahmen/beam-beta-smile-wienmobil-karte/
14.	Waze	Journey planner	Israel	https://www.waze.com/en/
15.	Moovit	Journey planner	65 Countries,	http://moovitapp.com/en-gb/

N.	Product	Category	Country	Link
			1000 Cities across Europe, Asia, Africa, Americas and Oceania	
16.	Superhub	Journey planner	Italy, Finland, Spain	https://ec.europa.eu/digital-single-market/en/content/superhub-tailor-made-mobility
17.	Google maps	Journey planner	Worldwide	https://www.google.com/intl/en/maps/about/
18.	MyCicero	Journey planner	Italy	http://www.mycicero.it/
19.	Carsh	Travel App	Italy	http://www.carsh.it/
20.	Musement	Travel App	Worldwide	https://www.musement.com/us/
21.	Moovel	Journey planner	North American cities	https://www.moovel.com/en/DE
22.	Mozie	Travel platform	Worldwide	https://dribbble.com/shots/2778926-Mozie-your-travel-assistant
23.	Wanderio	Journey planner	Italy (being expanded across Europe)	https://www.wanderio.com/?utm_source=google&utm_medium=cpc&utm_content=generico&utm_campaign=brand
24.	Sailsquare	Travel platform	Worldwide (mainly Italian market)	https://it.sailsquare.com/
25.	Jolly Ticket	Travel platform	Italy	https://www.jollyticket.com/
26.	Waynaut	Journey planner	Europe	http://websites.milonic.com/waynaut.com/
27.	Captaintrain	Journey planner	Europe	https://www.trainline.eu/?_ga=1.36586211.2106100525.1473680418&lang=en
28.	Cheapair	Journey planner and travel App	Worldwide	https://www.cheapair.com/
29.	Rome2Rio	Journey planner and travel App	Worldwide	https://www.rome2rio.com/it/

Table 5: Applications analysed by the market study

Based on the outcomes of the benchmark study we have a vision on how to enhance BONVOYAGE “attractiveness” with respect to its main competitors.

AS – IS Scenario Analysis

The main results of the AS – IS Scenario analysis highlight that currently available journey planners and travel apps (e.g. Rome2Rio, Moovit, Captain train, etc.) are well-advanced in the multi-modal, door-to-door journey planning, however they do not offer user-centred travel solutions, and do not always take into account the travel solutions environmental footprint.

In more details, existing journey planners and travel apps present high performing functionalities relating to:

- Single mode and Multi-modal travel solutions, at local, national and cross-border level, able to provide a door-to-door travel itinerary, with particular reference to local transports;
- Provision of detailed information on different transport modes included in the multi-modal travel solution (e.g. public transport line or number, travel duration, number of stops and connections, etc.);
- Provision of mobility real time information (e.g. traffic status, possible disruptions).

Nevertheless, currently available journey planners and travel apps show relevant weaknesses with respect to user profiling and single booking, payment and ticketing functionalities.

They show no significant progress in the definition and implementation of user profiling functionalities. During the creation and the update of the user account/profile, they only request and store user “basic” profile information (e.g. name, residence address, age, preferred transport modes etc.). Relevant information for the single user profiling, such as user specific personal preferences (e.g. cheap travel solutions, need to save time, preferred travel class, limited mobility and other special needs) are not taken into account to define specific categories of users. Therefore, they are not able to provide customized travel solutions for single users.

Existing multi-modal journey planners and travel apps do not allow the users to perform a single booking, payment and ticketing request for all transport modes included in the multi-modal travel itinerary, using the same system/page through which they search and select travel solutions. Actually, at the moment of the booking, payment and ticketing request the users are re-directed to different online portals of transport and travel operators involved in the multi-modal travel solutions, resulting in a complicated and time consuming process.

Contrary, platforms and apps managed by transport operators are able to provide several additional functionalities to the user, including the booking, payment and ticketing as well as the possibility to reserve or buy ancillary services. However they only deal with a single transport mode, lacking the multi-modality aspect.

Furthermore, other features and functionalities are not yet (or not properly) provided by most of journey planners and travel apps at stake. They include:

- Additional information related to the trip, such as planned measures on public transportation (e.g. strikes), additional information and services related to the point of arrival, such as weather, restaurants, hotels, culture and entertainment events, car sharing and car rental, especially for long haul trips;
- Travel solution carbon footprint;
- Possibility to activate a reminder with a related notification before the time of departure (using a connection with calendar, etc.);
- Assignment of "green" scores for each trip, with related awards and discounts;
- Sharing of trip information in real time through social networks and/or service provider's chat.

Analysis of the TO – BE Scenario

In the context described above, BONVOYAGE aims to bring to the journey planners and travel apps market the missing and innovative features and functionalities identified for the multi-modal, door-to-door journey planning and automatic re-planning, user profiling for the customisation of travel solutions and the special attention to the travel solutions environmental impact and users propensity to choose eco-friendly travel solutions. In this way, BONVOYAGE platform will be able to mark a significant progress by providing users: an enriched and comprehensive travel and mobility experience, personalised on the basis of users preferences and needs; a proper "travel assistance" able to monitor and support users during the journey (e.g. through automatic notification and re-planning in case of disruption).

The following Table 6 shows how the BONVOYAGE multimodal door-to-door journey planning platform provides new features and services able to meet market requirements.

Feature/Service	BONVOYAGE Platform Added value
Journey planning	**Travel Planning** In addition to the capability of BONVOYAGE platform to allow the user to search for a travel solution using basic filters (e.g. price, class category), the platform will be able to allow the user to select other information in order to personalize the travel solution. For example, through the BONVOYAGE platform the user will be able to choose: preferred path (e.g. shorter) and transport modes (e.g. bus or train), special needs, point of interest (e.g. stations) etc. The user will have also the possibility to insert other information about travel scope or day time and to check travel schedule before and during the journey. **Travel solution visualization** BONVOYAGE platform will be able to show to the users general information about

Feature/Service	BONVOYAGE Platform Added value
	the travel solution (e.g. stops, departure and arrival time; prices). However, the innovative feature of the BONVOYAGE platform will be the displaying of the multi-modal travel solutions taking into account the preferences expressed by the user (during the user registration and on the basis of his/her behaviour). Travel solution will be also prioritised and ranked based on their correspondence to the user profile (this latter is determined by declared user category, declared preferences, actual user mobility behaviour detected by BONVOYAGE platform on the basis of actual trips made by the user).
Real-time information	BONVOYAGE platform will offer the possibility to detect real time information/input from sensors/devices according to their time and space validity. It will give also the user the possibility to share real-time information on public transports traffic/status with other users and to set an alert which provides new real-time mobility information.
Feedback, Vertical Support and Re-planning functionality	BONVOYAGE platform provides the possibility: to send notifications on possible problems the App (e.g. problems with maps, places missing; feedback if misplaced); to send feedback on how to improve the App. BONVOYAGE platform offers the possibility to receive assistance during journey to deliver an opinion and satisfaction degree on development of the trip concerning the overall travel solution and/or each single mono-modal step (e.g. during the travel, when a change of vehicle happen; on-line support). BONVOYAGE platform offers also the possibility to: receive assistance by activating the function of rescheduling with the possibility of providing a negative feedback if applicable; to send requests for help to re-plan trip in case of unforeseen circumstances; to receive support to re-plan of the travel itinerary, through the intervention of a virtual assistance. The aim of these functionalities is to improve the customer experience.
Ancillary Services visualisation and purchase	BONVOYAGE platform, such as some currently available journey planner and travel apps, will be able to calculate and give the user information on location and distance of several additional services (e.g. car services, public services; restaurants, cultures, hotels, shopping etc). However, the innovative aspect will be the possibility for the user to purchase, through the same platform, these additional services. Furthermore, BONVOYAGE platform will be able to send users push notification targeted to the user containing suggestions and/or proposals about these services. Finally, other ancillary services of the BONVOYAGE platform will be the possibility for the user to buy tickets for parking, highway, access for restricted area/zone and municipal services.
User Profiling	As previously mentioned, one of the main innovative aspect of the BONVOYAGE platform is that it will provide a “profiling function”, on the basis of the preferences

Feature/Service	BONVOYAGE Platform Added value
	expressed by the users during the creation of the personal profile and on the basis of the behaviour of users over time. This functionality will allow the BONVOYAGE platform to return customized travel solutions.
Score Policy	BONVOYAGE platform will be able to assign score to the users on the basis of their behaviour, considering the selection and purchase of travel solutions more or less carbon footprint, through the definition of several user categories.
Other Features & Functionalities	Innovative feature of the BONVOYAGE platform will be also the possibility for the user to gather (and to check) points/scores based on: travel solutions purchased; quantity and type of information mobility shared with other users; achievement of objectives. Score assigned will enable the users to receive awards. Finally, other innovative functionalities of the BONVOYAGE platform will be the possibility to: share information on planned measures on rail, bus, metro, strikes, weather and places (e.g. restaurants); link status/emoticons to the profile; share status on social networks; use the chat to exchange message with other BONVOYAGE users; receive customized notifications about mobility information or suggestions; synchronise to and from calendar.

Table 6: Added value of BONVOYAGE

Compared to the journey planners and travel apps currently available, BONVOYAGE platform provides several innovative functionalities, as depicted in the Table 7 below.

Journey Planners & Travel platforms	*Integrated travel itinerary*			*Journey Planning*			*Ticket purchase*			*Ancillary services*		*Score Policy*	
	Single mode	*Multi-modal*	*Door-to-door*	*"Basic" journey planning*	*Real time info*	*Real time Re-planning*	*Single operator ticket*	*Multi-operators ticket*	*Integrated ticket*	*Services information*	*Services purchase*	*Green score policy*	*Other kinds of score policy*
Rome2Rio			●	●				●		●			
Waze	●				●					●			●
Superhub		●			●							●	●
Moovit			●		●								●
Google Maps			●		●					●			
Captain Train	●			●			●						●
Cheapair	●			●			●						
Smile/BeamBeta		●			●			●			●		
My Cicero		●		●				●			●		
Trenitalia App		●			●			●					●
BONVOYAGE			●			●					●	●	●

Table 7: Comparative innovations of BONVOYAGE

It is important to highlight that ticket purchase related functionalities do not directly fall into the project scope nor are being developed by technical work packages, due to the choice to focus the project research and development activities onto challenging issues (other than the simple integration of payment web-services), for example, on the **more advanced concept of tariff scheme design**, where a higher effort is needed to advance and bring them to the market.

3.6 Business Plan

The investigation of BONVOYAGE business-related aspects was carried out on the basis CANVAS business model methodology that served as a guideline to identify the key dimensions to be analysed and defined. It is detailed in deliverable D8.3.

The developed BONVOYAGE CANVAS business model describes in-depth, giving all necessary details, the following essentials elements:

- **Key partners** that might be interested and gain benefits from joining BONVOYAGE platform;
- **Key activities** required for BONVOYAGE platform to properly operating, ensuring service provisions to targeted customers, with respect to both technical and market related activities;
- **Key necessary resources** for the BONVOYAGE platform realisation, operation and maintenance, with focus on technology-related resources;
- The **value proposition** that BONVOYAGE will bring to the passengers and freight transport services market, highlighting its distinctive features compared to existing, competitor solutions;
- The **customers relationship** that BONVOYAGE will establish with its target customers, in order to guarantee a continuous interaction, collaboration and communication with them;
- **Customer segments** as target beneficiaries of BONVOYAGE value proposition;
- **Distribution channels** exploited to deliver BONVOYAGE services to the market in a smart, fast, efficient and cost effective way;
- **Cost structure**, that is identification of main costs to be afforded for BONVOYAGE realisation, operation, maintenance and update;
- Different **revenue streams** that might be exploited to generate income, based on the diversified market and customer segments targeted by BONVOYAGE platform.

It is worth mentioning that all the above elements were analysed considering that BONVOYAGE is a **valuable mobility service platform for transport services' developers as well as for**

transport service operators. They might both have different relevant interests in joining BONVOYAGE and rely upon it as an additional channel to reach their target customers. The importance of technology related aspects was also taken into account, as technology is a core element of the platform, allowing it to provide its services to the market in a competitive and user-friendly manner.

The CANVAS business model will serve as basis for the future definition of a fully operational BONVOYAGE business plan, that will provide evidence of the possible business opportunities related to BONVOYAGE platform implementation, management and maintenance, and the main stakeholders that may benefit from them.

3.7 Roadmap

The following Figure 5 shows the project's roadmap, reporting step-by-step the main results obtained so far and official project milestones. The results reported in Figure 5 are the following:

1. June 2015 – Management structures and technical infrastructure needed to run the project fully operational
2. October 2015 – Initial definition of use cases and reference architecture
3. January 2016 – Design of advanced functionalities of the Internames Communication System and preliminary design and implementation of travel-centric services
4. January 2016 – First draft of BONVOYAGE's architecture
5. January 2016 – First live demo of ICN-IOT middleware showing Internames functionalities
6. February 2016 – First design of OpenGeoBase, a decentralized large scale storage system used for building our georeferenced mobile and web applications
7. April 2016 – Consensus on the Federated Architecture
8. June 2016 – Orchestration and Data Sources fitting in the concept of federation
9. September 2016 – Prototypes of the main platform components

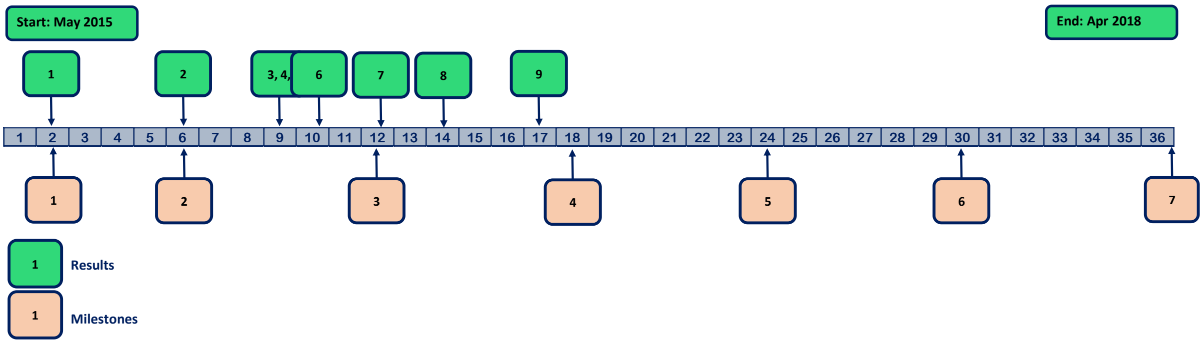


Figure 5: Project roadmap

3.7.1 Key development milestones & timings

The official project milestones, along with their estimated date, are reported in the following Table 8, which is extracted from the original proposal.

Milestone number	Milestone name (and short description)	Estimated date	Date	Means of verification
1	**Project fully operational.** Management structures and procedures, including standard formats and forms for project documentation ready. Composition of boards fully defined. Technological infrastructure to support cooperative work fully operational (web server, document server, version control system for sources files, mailing lists, management & report tools, etc.). Planning of Communications, Dissemination and Standardisation activities.	Month 2	01/07/2015	D1.1, Project technological platform office fully operational (verified by all partners), I6.1
2	**Mid-year milestone 1.** Technical WPs producing first results, including selection and abstractions of use cases and function abstractions, draft system architecture.	Month 6	01/11/2015	I2.1, I2.2, D2.1
3	**End of cycle 1.** System architecture and interfaces. Preliminary solutions for the Communication system, Transport functionality and Adaptation functionality.	Month 12	01/05/2016	D1.3.1, D1.4.1, D2.2, I3.1, I3.2, I4.1, I5.1, D8.1, D8.4
4	**Mid-year milestone 2**: First project review; first edition of the Project vision and roadmap. Report on dissemination and open source contributions and standardization. First report on exploitation plans. Definition of communication networking functionality; Design of the Intelligent Transport Functionality; Preliminary definition of Technology/Operator dependent interfaces.	Month 18	01/11/2016	D3.1, D4.1, I6.1

5	**End of cycle 2**. Definition of Publish/Subscribe and security functionality; preliminary definition of Travel-centric and participatory sensing services. Design of the adaptation functionality. Definition of Technology dependent interfaces. Preliminary Modelling and performance analysis.	Month 24	01/05/2017	D1.3.2, D1.4.2, D3.2, I3.3, D5.1, D6.1, I6.2, I6.3, D8.2, D8.5
6	**Mid-year milestone 3 and End of cycle 3**. Final definition of Travel-centric and participatory sensing services. Development and validation of the Intelligent Transport Functionality. Development and test of the adaptation functionality. Definition of Apps. Integration plan completed. Platform integration and first prototype available.	Month 30	01/11/2017	D3.3, D4.2, D5.2, D6.2, D7.2
7	**End of phase 3 and of the project**. Second project review; second review report. Second edition of the Project vision and roadmap; second report on dissemination and open source contributions and standardization. Dissemination reaching wider audience. Second report on exploitation plans. Final Modelling and performance analysis. Final release of platform and use case code; third report on dissemination and open source contributions and standardization.	Month 36	01/05/2018	D1.3.3, D1.4.3, D7.3, D8.3, D8.6, D8.8

Table 8: Project's milestones

3.7.2 Dependencies and risks

In Table 9 we report the risk originally envisaged in the proposal and we add a column reporting related issues, if any.

Description of risk and related probability and impact	**WP**	**Proposed risk-mitigation measures**	**Risk state of play**
Inadequate coordination Probability: Low Impact: High	WP1	CNIT has extensive experience in the coordination of EU projects. The management structures and procedures outlined in this proposal ensure that project management can closely supervise the delivery of the expected results (internal intermediate results as well as official deliverables). Meetings of the MB will identify potential problems and react early, e.g., by reducing the functionality of a prototype or by organizational changes. The Consortium inherits some management procedures and working relationships among some of	Risk did not materialize

		the Consortium members, tested during previous EU project and have been shown to work very effectively and which have been very favourably judged by reviewers during technical reviews. The "management risk" attached to the work is therefore minimal.	
Conflicts among the partners Probability: Low Impact: Medium	WP1	The work plan has been designed so that tasks and responsibilities are clearly assigned so that conflicts are unlikely to arise. In previous projects, the BONVOYAGE management team has already successfully handled conflicts between partners. The strategy applied mixes strong leadership by the coordinator with consensual discussion and decision-making within the GB. Should unresolvable conflicts arise, their outcome will be handled as detailed in the partner dropout and "delays" risk.	Risk did not materialize
Drop-out by a partner Probability: Low Impact: Medium	All	Partners in the project are major public institutions or large companies and a rather "large" SME, which are very unlikely to fail. Drop out is highly unlikely also for academic partners, who participate with senior researchers who have been with their institutions for a long time. The risk may be marginally higher for large companies, where parent companies or central management may decide to discontinue commitments for reasons not under our control. To limit the impact of such withdrawals, all WPs include at least a second partner with sufficient expertise to take the lead of the activity. In addition, it is true that partners' planned work complement each other without significant overlaps, but we allowed for a limited redundancy and sharing of tasks, which mitigates this risk. Given that no partner has more than 14% of the total manpower, drop out of partners with no leading roles will be easily handled by either redistributing the work between other partners, recruiting a new partner, or revising the DoW to deal with the withdrawal.	Risk did not materialize
Delays in the design and development of key project's elements Probability: Medium Impact: Medium	All	Academic partners of BONVOYAGE have extensive experience not only in research work but also in the deployment of demonstrators and test-bed, as proven by a very successful track record. The consortium includes companies certainly capable of delivering the technological components and software foreseen in the work plan. The Work Plan contains intermediate steps	Risk did not materialize

		and partial results. The task schedule is such that there is sufficient overlap between the various phases of the project (design; platform development; application development; deployment) so that moderate delays can be accommodated and recovered without much trouble. Also, results from the various stages of the project are not monolithic entities so partial unavailability of some elements will not entirely block the next stage of the activity. As an example, system development can start with partial results from WP3-6, and same goes for the integration activity in WP7 as preliminary implementations of the components in WP3-6 are available. The development of use cases will be done in parallel.	
Feature in the use-case is not supported by the platform. Probability: Medium Impact: Low	WP5	There is a risk that the use-cases identified have features that are unsupported by the system. Given the partner contributions in other WPs throughout the project, the use-cases should be a natural progression of work and are not expected to differ greatly from those determined at the time of writing the proposal. Some refinements for the abstraction and models are expected, as feedback from WP7 and as such new use-cases or revisions to the use-cases. WPs in general are planned to be slightly longer than strictly required to take into account the possible feedback and change of requirements.	This risk did not materialize concretely, but several discussions about coverage of use-cases by the implementation have already been started. When integration activities enter a more advanced stage it will be possible to better assess this risk and correctly manage it.
Technology is superseded by competing solutions and/or patents are filed by competitors Probability: Very low. Impact High	All	Partners have connections with other leaders in the industry and academia so will be aware of other projects that are on-going and where there may be overlaps. The partners are also involved in standardisation groups so will see motions by other groups in similar areas. If competing solutions are created, then collaborative efforts will be sought in the first instance, and then failing this, efforts will be made into revising the scope and target areas of BONVOYAGE.	Risk did not materialize
Standards bodies not accepting BONVOYAGE's work Probability: Medium Impact: Medium	WP6	Several partners have extensive experience in standardization work and are already involved on topics related to the project's ones. In addition, standardization bodies operate on long timescales, often exceeding the lifetime of this project, thus contribution to a standardization body also means providing useful input to the process without necessarily	Risk did not materialize

		having a standard formally accepted.	
Lack of exploitation of project results Probability: Low Impact: High	All	Commercial and institutional partners of BONVOYAGE intend to exploit and push BONVOYAGE solutions. The project's dissemination and communication activities will allow the project to reach a very large base of possible customers, and to test and advertise BONVOYAGE in real markets, a further assurance of real exploitation.	Risk did not materialize

Table 9: Envisaged risks

4 Work performed so far

4.1 Current achievements: R&D

In this section, we report the work performed as regards R&D activities.

By reviewing the progression in time of the results achieved by the project, as reported in the above roadmap in section 3.7 and depicted in Figure 5, it is possible to read through the story of BONVOYAGE's research and development activities during the first half of the project's lifespan, as follows.

1. The challenge of a continent-wide platform that fosters an ecosystem of novel Intelligent Transport Systems and guarantees openness and a level of performance able to sustain millions of real-time data sources, plus user profiling and live re-planning of multimodal itineraries, can be tackled by centralized or distributed approaches.
2. Research in the area Future Internet is leading to novel implementations of scalable network cloud infrastructures for efficient dissemination and discovery of information sources.
3. The European community advocates an approach based on interlinking and interoperability across borders of ITSs.

BONVOYAGE responded to the challenge by:

- Designing a rich functional architecture.
- Inserting the rich functional architecture that was designed during the first months of its activity into the context of a federation.
- Technically enabling the concept of federation by the Internames network layer and the Orchestrator
- Fitting the federated architecture in the context of the latest EU directive on ITSs

By federation, in contrast to a generic distributed or P2P system, we mean a group of computing or network providers agreeing upon standards of operation in a collective fashion, so that **inter-operation of such group of distinct, formally disconnected networks, which have different internal structures**, is obtained.

The rest of this Section is organised as follows. First, we briefly summarise our first half achievements, and then we detail the work done in each Work Package (WP).

4.1.1 In a Nutshell

The work performed by BONVOYAGE during the first half of the project has covered several aspects, including:

1) definition of use cases, system requirements, reference scenarios and functional architecture, performed in WP2;
2) design and development of the Internames Communication System, with publish/subscribe and travel-centric services, performed in WP3;
3) methodological and algorithmic development of the core Intelligent Transport Functionalities: (i) User Profiler Tool for personalizing multi/inter modal services, (ii) Multi-Objective Optimization Tool for optimizing and controlling multimodal services, and (iii) Tariff Scheme Design Tool for travel centric multimodal services, in WP4;
4) handling of the heterogeneous data, relevant to end users and to Transport Operators, and translation of them into homogeneous metadata, performed in WP5;
5) seamlessly interacting with the heterogeneous external actors of the BONVOYAGE platform, and working on the sensing and actuation functionalities of the BONVOYAGE platform, in WP6;
6) the fact that System Integration and Validation WP (WP7) has been anticipated to month 15, because of the potential advantage of gaining earlier practical insights into how the various outputs from the other WPs can be successfully integrated and to show a practical demonstration of project achievements at the first project review.
7) Communication, dissemination, standardisation and exploitation activities, in WP8.

We report in the following a more detailed description of the work performed in each WP.

4.1.2 WP2: System Requirements and System Design

WP2 activities at month 18 are closed.

The first concrete objective of this work package has been to gather and specify the BONVOYAGE system requirements combining user's needs (administration, public transport, fleet operators) and transport operators perspectives (economic consideration, available service) as well as economic and technological perspectives (mobile apps, sensors, embedded systems, wireless devices).

Creating short stories has helped in the identification of the main capabilities to be offered by the platform. They have evolved into meaningful, business oriented use cases and a set of four reference scenarios.

Main stakeholders have been identified and grouped and BONVOYAGE terminology defined, covering key terms. Also a questionnaire (internally called BONVOYAGE services/capabilities template) was created with the purpose of collecting information on existing services and solutions available in the cities participating in the validation scenarios.

A set of functionalities has been defined addressing the identified requirements and these functionalities have been grouped into functional modules. As result of this process, the preliminary BONVOYAGE reference architecture described in the proposal has evolved into a much more detailed functional architecture.

A revision of relevant standards for the BONVOYAGE platform has been carried out and existing ICT solutions and services available in the targeted BONVOYAGE cities have been analysed to better understand the validation context for the system.

In order to select the most innovative functionalities that demonstrate the project findings, a web based software tool has been developed. This tool has supported the verification of the relationships between requirements, use cases, functionalities and modules. The architecture analysis tool allows associating a weight to each requirement and functionality, in order to rank uses cases based on their impact on requirements and functionalities.

Input and output data objects have been defined and assigned to each functionality, and a first set of software components have been identified and described, ensuring that our top-down design methodology is complemented with a careful bottom-up evaluation of the software prototypes we currently have (either developed for research purposes throughout the first year or pre-existing).

4.1.3 WP3: Internames Communication System

Internames acts as a bus to provide secure communication among all components, devices and nodes of BONVOYAGE.

Inputs from WP2 (with particular attention to the definition of the perimeter of entities involved in the platform) have been carefully taken into account for conceiving a hierarchical naming schema able to uniquely identify, in a trustworthy way, travel-centric information, actors, and service operations. Additional inputs have come from the most recent developments in the context of the General Transit Feed Specification and DATEX II standardization activities, and have been taken into account when formulating the travel-centric and participatory services that this work package provides.

Internames Service Layer

The work package has begun by accomplishing the design of core Publish/Subscribe and Request/Response primitives within Internames. The resulting communication framework is able to support a name-based data exchange between data producer (for Instance, Trenitalia) and data consumer (for instance, a travel operator) in a heterogeneous network made up of different realms (i.e., IP, NDN, and PURSUIT). Moreover, the Name Resolution Server (NRS), which is a logical entity of Internames involved in routing-by-names operations in a heterogeneous network, has been significantly extended for handling announcement and push notification services in an efficient and scalable manner. The extended NRS integrates a number of interoperating blocks, which are: NRS Service layer, Routing Capability Engine, NRS Retarget

Engine, NRS Forward Manager, Local Data Base Manager, and Publish/Subscribe Engine. Together, they constitute an Internames Service Layer able to support dissemination of travel centric data, as well as the design and the development of sophisticated travel-centric services.

Publish/Subscribe, security and Travel-centric services

Tasks 3.2 and 3.3 are correlated by a very high degree of synergy. Their combined aim is to offer to the overall platform a set of Travel-Centric Services which, based on pub/sub, are able to optimize data distribution in the context of travel planning applications.

A Java library was developed, which offers well-specified APIs for Publish/Subscribe operations and is thus easy to integrate with other software components of the overall architecture. On top of this Publish/Subscribe front-end, a specialized set of Publishers has been developed, tailored to different data-sources being considered in BONVOYAGE, as candidate data-sources for the demonstrator. Namely, travel-centric data coming from the Norway NPRA servers and data coming from the City of Bilbao (in collaboration with WP5) are being monitored and updates are published as soon as changes are detected, and routed to all interested Subscribers by means of the Publish/Subscribe front-end (see a more illustrative description of the laboratory prototype derived from this activity, in section 4.2.6).

The activities above are on-going, and being carried-on by continuously interacting with ATOS and the Metadata Handling Tool technologies, and take into account the design of software components and data structures coming from WP4.

Additionally, the OpenGeoBase spatial database has been devised, which is based on the Internames Service Layer (exploiting all the advantages of ICN) and is used to support generic ITS applications that want to discover public travel data repositories (e.g. GTFS files) available in a given geographic region. OGB is the cornerstone of the federated BONVOYAGE architecture, because it performs indexing of the resources available to the federation and allows discovering them. OpenGeoBase offers cutting-edge security functionality and a flexible API. The user interface is based on GeoJSON format and its security framework is based on an Authentication Center (AUC), which stores security keys and certificates that are necessary for the application of data-centric security features. Preliminary performance benchmarks have been carried out versus MongoDB. A first release of OGB has been made available to the project and published on the BONVOYAGE web site. A brief operative illustration is given later, in section 4.2.5.

WP3 also worked on the issue of video streaming transmissions in presence of network caches, such as the Internames ones. Video streaming services can be useful e.g. for ITS-related applications exploiting cameras distributed in the environment, whose location can be discovered by using OpenGeoBase.

4.1.4 WP4: Intelligent Transport Functionality

WP4 deals with the design and (methodological and algorithmic) development of the core of the BONVOYAGE platform, namely the Intelligent Transport Functionalities: (i) User Profiler Tool for personalizing multi/inter modal services, (ii) Multi-Objective Optimization Tool for optimizing and controlling multimodal services, and (iii) Tariff Scheme Design Tool for travel centric multimodal services. The main objective is to provide personalized control decisions tailored to the requesting users (e.g. optimal multi-modal travel, possible multi-modal tariff schemes, itineraries and tariffs for the delivery of goods). Personalized control decisions should be optimal with respect to user profile and should aim at promoting the use of socially desirable bundles of transport services.

Besides outer strong connections between WP4 and other technological WPs in the BONVOYAGE project, there are very strong inner connections among the three main tools designed and developed in WP4.

User Profiler Tool

CRAT proposed an User Profiler Tool whose key difference with respect to previous control and/or learning based approaches consists in jointly taking into account the user request submitted to the Multi-Objective Optimization Tool and the actual choice carried out by the user as he/she returns one or more travel solutions. In this framework, we consider the travel solution chosen by the end-user as a “user feedback” and use this choice in order to identify the actual user behavioural profiling and eventually producing the so-called Personalized Optimality Criteria, which drive the Multi-objective optimization tool in providing personalized travel solutions. The UPT is based on:

- definition of a User Data Model (UDM) for development of data mining and machine learning models and algorithms
- design of a Datalogger for statistical-inference-based monitoring of the Level of user Stress (LS) and of the User Transportation Mode (UTM). Please see a more illustrative description of the laboratory prototype derived from this activity in section 4.2.2.

CRAT and CEA are carrying out a fruitful cooperation on designing advanced machine-learning-based models for personalizing multimodal transport services. The work performed brought to an advanced methodological framework for personalization of the services offered by a generic Intelligent Transportation System. The User Profiler Tool is conceived to extend traditional ITS functionalities by automatically learning implicit user preferences from the user behaviour, even in the case the user preferences are in contrast with the ones explicitly declared by the user. CRAT proposed a data driven, user centric, control based framework for the personalization of the services. The proposed framework is sufficiently general to control a generic Intelligent Transportation System.

In order to define the main data features appearing in the proposed framework, CRAT contributed to the BONVOYAGE Questionnaire by proposing specific questions about travel habits and travellers' preferences and needs.

Partners designed the User Profiler Tool as well as all software components and provided a preliminary implementation of the most important software modules. Thanks to an intensive activity of real data collection about user preferences and habits in terms of door-to-door, long distance travels, test and validation activities concerning each software component have been started and are still on-going (see a more illustrative description of the laboratory prototype derived from this activity in section 4.2.1).

Multi-Objective Optimization Tool

The technical discussion that defined the boundaries of the trip control functionalities and the integration strategy with the trip planning tools was mainly between CRAT and SINTEF. The main contribution is the definition of the orchestrator concept by SINTEF, and a decomposition strategy consisting of a global extra-urban trip planning and a local intra-urban trip planning.

CRAT proposed a preliminary urban soloist (see a more illustrative description of the laboratory prototype derived from this activity in section 4.2.3) for local travel solutions that has the strength of being fully in line with the methodological framework for personalization of services offered by the UPT. The personalization of the mobility solutions and the integration of different transport modalities increase the complexity of the mathematical programming-based trip-planning problem with respect to other commercial solutions. The main contribution is the definition of the local, intra-urban multi-passenger trip-planning problem by considering, besides traditional collective transportation means like metro, bus and tram, novel transportation services like carpooling operated by private people; the solution has been designed to meet both user needs, in terms of travel request, and user preferences.

The activities supporting the orchestration of the local soloists with and the global trip planning, as well as their integration in the federated architecture, are still on going.

Tariff Scheme Design Tool

The research started by an highlight of possible evolutions to strengthen the Tariff Scheme Tool innovation capabilities, comprising of an analysis of factors pushing the user towards socially desirable mobility solutions and the definition of a Tariff Scheme Tool proposal, with identification of advantages and disadvantages. TRIT and CRAT undertook a continuous dialogue for the precise definition of objectives and work methodologies, focusing both on research and on business needs to be addressed.

CRAT performed a preliminary study on the quality of service at multimodal hubs aiming at identifying the dimensions of quality of travel (i.e. the parameters characterizing the quality of travel) for passengers at multimodal hubs, in the case of long distance trip chains.

The definition of the algorithm for dynamically determining pricing rules when two transport operators (one airline and a high-speed rail (HSR) operator) plan to establish a partnership is already consolidated, though still on going. Two main scenarios have been considered:

- the airline and the HSR are pure competitors (benchmark scenario)
- the airline and HSR form a partnership to operate a multimodal market (integrated scenario).

Please see a more illustrative description of the laboratory prototype derived from this activity in section 4.2.8.

Membership Management

Trenitalia performed core work regarding the concept of membership management. It is composed of:

- A "green" Score Policy.
- A Loyalty Programme.

They both aim to reward users that use BONVOYAGE to plan and purchase travel solutions, but with different ultimate goals: the "green" Score Policy intends to "push" passengers towards eco-friendly mobility choices and fosters the selection of means of transports with low environmental impact, while the Loyalty Programme is intended to reward users showing a high level of "fidelity" to BONVOYAGE. Please see a more illustrative description of the laboratory prototype derived from the green Score Policy activity in section 4.2.7.

All of the activities performed so far are detailed in Deliverable D4.1 - Design of the Intelligent Transport Functionality.

4.1.5 WP5: Adaptation Functionality

The goal of this work package is threefold:

- to handle the heterogeneous data, relevant to end users and to Transport Operators, and to translate them into homogeneous metadata (Metadata Handling Tool);
- to design and develop the Multi-Modal Mobility Database (which stores the Dynamic Present Context, the User Profiles, and supports WP4) and the Database Services;
- to design and develop the functionalities necessary to adapt the technology-independent Personalized Control decisions provided by the Intelligent Transport Functionality (developed in WP4) to the specific Transport Operators (Service Adaptation).

Task T5.1 *Database design and development* and T5.2 *Metadata Handling Tool* of WP5 started in month 9 of the project. During the period, WP5 has produced intermediate delivery I5.1 *Design of the adaptation functionality*. The final design is strongly dependent on the overall architecture and in particular linked to the design of all WP4 components that make up the Intelligent

Transport Functionality. Task T5.3 *Service Adaptation* started in month 13 of the project. All tasks are therefore now in progress.

Important results of WP5 are related to the scrutiny of GTFS, DATEX II and WFS data formats and the corresponding data available at the NPRA (Norway) and City of Bilbao servers. This has led to the integration of these data source into the BONVOYAGE data federation and the OpenGeoBase discovery service, as remarked above.

Overall, R&D results of this WP will become more apparent in the second half of the project.

4.1.6 WP6: Multimodal Integrated Interfaces and Apps

The main goal of this work package is to design and develop all the mechanisms needed to seamlessly interact with the heterogeneous external actors of the BONVOYAGE platform. In line with this, this WP is also in charge of the sensing and actuation functionalities of the platform. More specifically, the WP comprises the following main objectives:

- Design and development of the technology dependent interfaces towards the external actors (transport operators' systems, data sources, end user applications).
- Design and development of an application for the Mobile Participatory Sensing Services.
- Design and development of an application for Mobile Information Services.

WP6 started at M9, in a continuous interaction with the architectural and requirements perspective work done in WP2. The system components that will be developed in WP6 were identified and its functionality specified from an architectural perspective. The dependencies and communication with other work packages were discussed with a focus on WP5.

Technology/Operator dependent interfaces

WP6 has defined a concept for integration and customisation of services in cooperation with WP5, and the most important result is the focus on the development of an advanced format for route information exchange. The format is compatible to the open source Ariadne format, but has developed a set of key extensions, because this activity is synergic to the concept of orchestration and is going to become the main enabler of the federation of soloists. It defines the semantics and syntax of the communication channel between soloists and the orchestrator. This activity is on-going.

App

Within task 6.2, WP6 has started to discuss and specify architectural design and interfaces issues of the mobile application. Furthermore, the requirements for the first release of the mobile app were specified and a first draft for wireframes was created.

4.1.7 *WP7: System Integration and Validation*

The main goal of this work package is to carry out the system integration, the system test, the deployment and the validation of the developed BONVOYAGE platform.

More specifically, the WP comprises the following objectives:

- Definition of an accurate integration plan.
- Integration of the various tools, components and applications developed in WP3, WP4, WP5 and WP6.
- Tests of the correct inter-module interoperability and final system tests.
- Definition of the deployment guidelines for the final validation.
- Validation of the integrated system with real end-users and transportation operators and evaluation/assessment of the results of the validation campaign.

The System Integration and Validation work package was initially planned to start in M23 of the project. During the Fourth General Assembly, the BONVOYAGE Consortium decided to prepare and present an integrated demo for the Review Meeting planned in November 2016. This decision implied an earlier beginning of the work planned in WP7 – System Integration, initially planned to start at Month 23 (March 2017).

The reason, which lead the Consortium to this decision, is related to the potential advantage of gaining earlier practical insights into how the various outputs from the other WPs can be successfully integrated and to show a practical demonstration of project achievements at the first project review. Furthermore, the Consortium believes that early integration will generate useful feedback, to be used in improving the design activity. Also integration activity stimulates partners to work better and together, as when a component is needed for integration, the responsible partners are more committed to provide it. On the other side, the project produced enough "material" to be integrated: for instance, SINTEF's and CRAT's optimization algorithms and related software; CNIT's ICN network and related software, real data coming from several partners; all this can be made available to Fluidtime that can thus develop applications.

The Coordinator formally exposed justification about the Gantt changes to the Project Officer, who approved the early start of the WP7 at the date of the related official communication by the coordinator (21st July 2017).

The new starting dates of each Task are:

- Task7.1: New Starting date M15 Instead of M23
- Task7.2: New Starting date M18 instead of M25
- Task7.3: Staring date M30 – No change

This work package has started on the 21st of July; the first outcomes of the activities and tasks done under the umbrella of the BONVOYAGE integration are:

- Discussion and assessment on the integration strategies.
- Identification of technical components to be integrated
- Development of first steps of the integration plan.

4.1.8 WP8: Communication, Dissemination, Standardization and Exploitation

This Work Package aims at disseminating the project results among interested end-user communities (transportation operators, municipalities, manufacturers, etc.) and general public as well. Moreover, this WP investigates exploitation strategies for the project results and includes interfacing activities with relevant standardisation groups and more in general communication activities.

More specifically, the WP comprises the following objectives:

- Setup of the communication instruments (e.g., logo, website, promotional literature; this WP will care for the content to be communicated, the related technical tools are dealt with in WP1), in order to prepare and execute clear and effective communication and dissemination activities for the whole duration of the BONVOYAGE project.
- Development of the communication, dissemination and the exploitation plans.
- Publication of results to prestigious national and international journals and conferences, in the areas of transportation systems, optimization, telecommunications, economics.
- Development of the standardisation plan and contribution to relevant standardisation work.

In the context of communication activities, WP8 created and populated the project web site (http://bonvoyage2020.eu/), as well as the social networking channels specified by the plan (LinkedIn Group and Twitter Account). The work package created the general presentation about the project, and produced a 1-page and 2-page factsheet, project flyer and poster.

The web site is frequently updated with the support from the different partners. Activities from the project are also reported on social networks (e.g. LinkedIn and Twitter) where stakeholders are engaged in exchange on the project outcomes. The dissemination plan template has been approved and is filled in by the partners. It allows the monitoring of activities from the whole consortium related to information given on the project at different audiences. It aims at creating synergies among the several BONVOYAGE dissemination activities from each partner. BONVOYAGE partners have been involved in several events at EU level. The planning of dissemination activities involves common activities of partners.

Several dissemination activities have been performed. Results of this work package are reported in full details in deliverable D8.1.

4.2 Current Achievements: Laboratory Prototypes

During the first half of the project, several laboratory prototypes have been developed and used by the partners to test and research the key components of the architecture. Integration activities have been anticipated to month 15 (see above, WP7 activities), so that the integration of the prototypes towards the final testbeds is gaining momentum.

A mid-term review is planned at month 19 (November 2016), hence some of the laboratory prototypes described in the following sections are going to be re-purposed for demonstration at the review event.

4.2.1 User Profiler Tool @CRAT

This prototype is managed by CRAT, in Rome.

Objective: show how global pre-trip plans vary on the basis of user's personalized parameters.

Brief Description: a user makes a query, for instance asking a trip between two European cities, for the first time, and receives a ranked list of multi-modal travel solutions. After being profiled, the same query, issued at a later time receives a (different, personalized) ranked list of travel solutions.

The prototype operates on the set of input data taken from Registration of User (age, gender, user category) and from User Query (source, destination, departure time, allowed transportation means, user preferences). The core of the User Profiler Tool is the *User Centric Control System* (UCCS), shown in Figure 6.

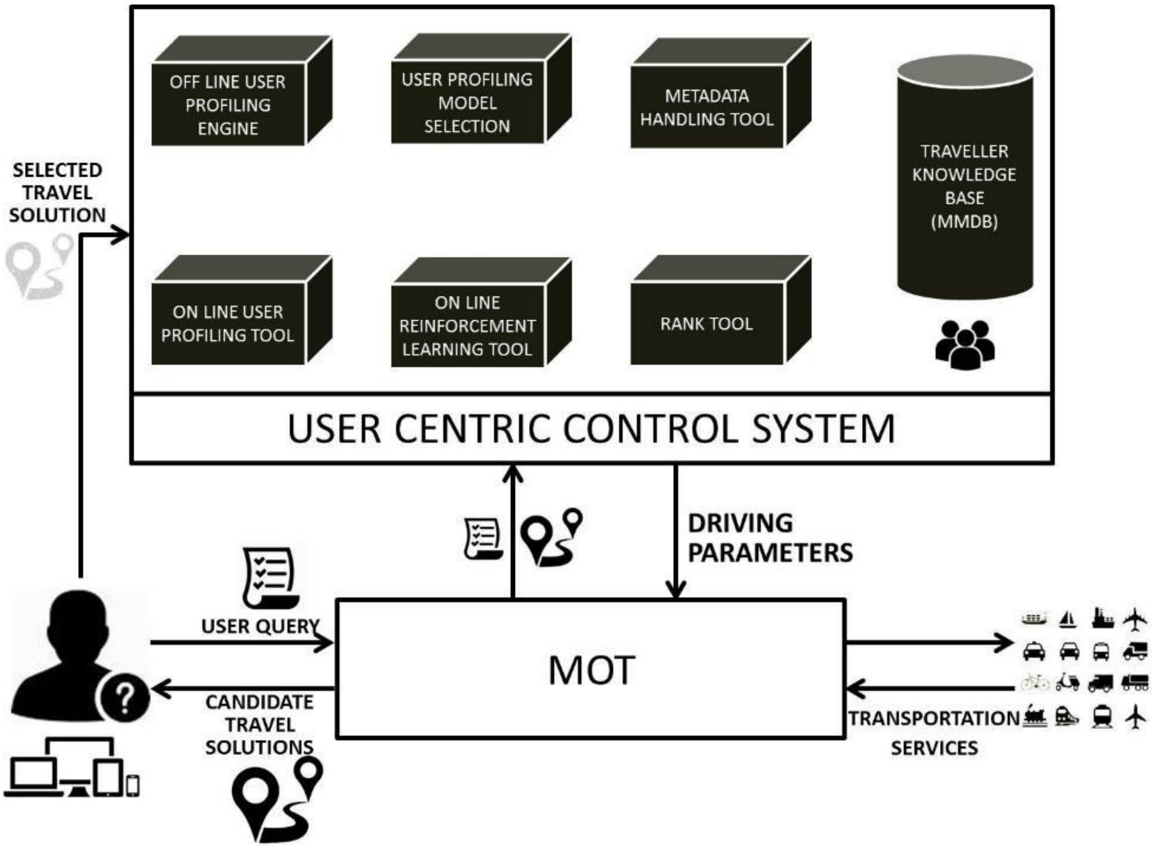


Figure 6: Multi-Objective Optimization Tool (MOT) and User Centric Control System (UCCS)

The prototype is able to take into account both user profiles and user history for personalization purposes. The *User profile* based personalization modules are:

- **Off line User Profile Engine**, in charge for identifying automatically a set of user profiles, each of them characterized by a subset of commons travel preferences and constraints; the user profiles we are interested in are conceived as the centroids of homogeneous clusters (or groups) of users showing similar behaves and preferences in terms of multimodal transportation means and services; once extracted the best partition of the users (according to the best parameters, see User Profiling Model Selection) the user profiles are indicative patterns in terms of travel preferences and constraints of a group of homogeneous, statistically relevant travellers;
- **User Profiling Model Selection** is the actual control panel of the User profile based personalization modules; the model selection is a very important task in any machine learning application, since once the learning algorithm is identified (in this case, the unsupervised, partitional k-means algorithm within the Off line User Profile Engine), the parameters controlling the effectiveness and the efficiency of the algorithm must be carefully adjusted in a suitable domain in order to allow the machine learning algorithm to extract useful information from the data analysis task;

- **On line User Profiling** assigns any user of the BONVOYAGE platform a user profile in terms of the most similar cluster (or group) and allows a complete characterization of the user from the travel preferences and constraints' point of view; in particular, in case of new user interacting with the BONVOYAGE platform for the first time, the user profile assigned automatically by the On line User Profiling provides information about potential driving preferences and constraints that the user share with all the users belonging to that specific user profile.

The User history based personalization modules are:

- **On line Reinforcement Learning Tool**, managing and updating different data structures according travel features automatically extracted from the interactions between the user and the BONVOYAGE platform; the main aim is providing driving parameters indicating the user's preferences and constraints basing on his own past interactions with the BONVOYAGE platform;
- **Rank Tool** provides an ordering criterion in the family of (unordered) travel solutions according to the driving parameters identified automatically by the On line Reinforcement Learning Tool.

The **Travel Knowledge Base** is a portion of the Multimodal Mobility Data Base (MMDB) developed within WP5, and consists of all data managed and analysed by the Off line User Profiling Tool and the On line Reinforcement Learning Tool.

4.2.2 Personalization via sensors @CEA

This prototype is managed by CEA, in Grenoble.

Objective: infer, by aggregation of sensor data, specific user profiles, for instance that User A never rides a bike, User B never takes a plane; User C is stressed by the plane, User D is not stressed at all by the car; User E has a low carbon footprint.

Brief description: there are two prototypes, one performing real time assessment of user's transportation mode (UTM) from various sensors of his Android smartphone while he is on the move, and the other one providing the stress level of the user (USL) by analysing data from an Empatica E4 watch he is wearing.

Both prototypes are based on a common framework composed of the following modules: **Datalogger App**, **Database**, and feature extraction and classification algorithms exploiting them.

USL Datalogger App: The datalogger consists in acquiring physiological measurements together with information about stress. The Empatica E4 wristband presents several advantages: it is not very obtrusive; it allows collecting raw data of skin conductance, photoplethysmogram (PPG) and body temperature. The assessment of stress state is accomplished by the App shown in Figure 7. Data from Empatica E4 can be collected after the experiment by using the Empatica platform or online by the smartphone by using Empatica's Android code.

USL Database: We have already collected several data in our prototype's database:

- We use the MIT driver database available on Physionet[5].
- We use a database collected in a laboratory settings with well-known protocols generating stress: Trier Social Stress Test (TSST) which is designed to exploit the vulnerability of the stress response to socially evaluative situations, and the Socially Evaluated Cold-Pressor Test (SECPT), which is a physical stress protocol performed by immersing the hand into an ice water container, usually for three minutes, and measuring physiological changes. Its response is clinically indicative concerning vascular response and pulse excitability. We also use a less stressful task called d2 in which temporal constraints are introduced. For those experiments, 20 users are considered for each of the 3 experiments. The same users also performed control tasks, corresponding to the same activity without stress elements at different occasions.
- A stress database, which records interns presenting their work in real-life conditions, has also been created. For this, wearable sensors were used, together with questionnaires for perceived stress level.
- A stress database representing a workweek of different subjects, corresponding to real-life situations that typically appear in daily life, is used too.

[5] https://physionet.org/physiobank/database/drivedb

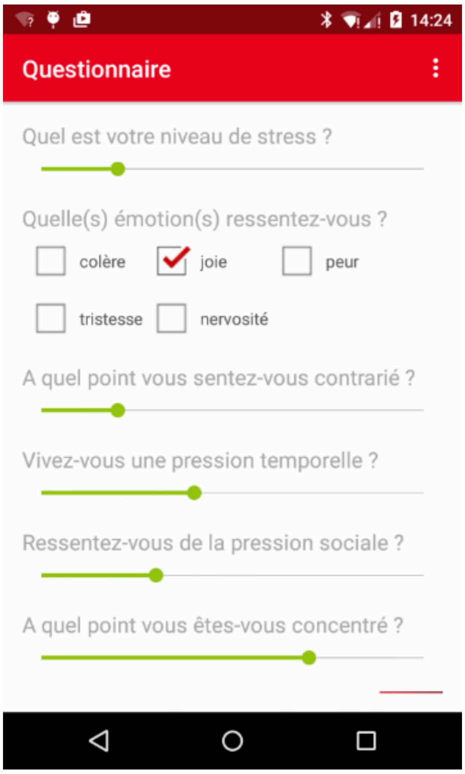


Figure 7: USL Datalogger front-end

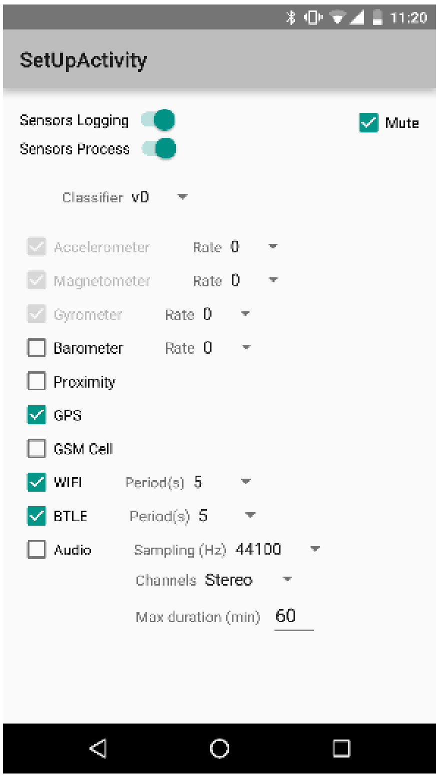


Figure 8: UTM Datalogger front-end

UTM Datalogger App: 15 modes have been pre-determined and wired into the App: still, walk, run, bike, electric bike (ebike), motorbike (moto), car, electric car (ecar), bus, electric bus (ebus), tramway, metro, train, plane and boat plus an additional class named “other” to manage data that are incorrectly classified in the pre-defined transport mode classes. This way other transport modes used by one user (for example: paragliding or windsurf board) can be taken into account. During acquisition, the Android app logs the information about the transportation mode and a set of chosen sensors available on the smartphone. The recorded files contain data from the sensors in the list below as well as the transportation modes annotated by the user and some technical information such as the version of the logging app. The sensors available for now are:

- Accelerometer,
- Magnetometer,
- Gyroscope,
- Barometer,
- Proximity sensor,
- GPS,
- Wi-Fi,
- BLE (Bluetooth Low Energy),
- Audio data.

We can set some parameters such as the sampling frequency or scanning frequency from the Set Up window shown in Figure 8. This Android logging app is used to create the necessary database to construct a transportation mode classification model.

UTM Database: The database was set up by making a call for volunteers among CEA employees, in Grenoble, France. Each user was taught how to use the datalogger. They were asked to use the datalogger during commute, business or leisure trip, and for the duration of one to several days. Once they returned, data stored in the smartphone were manually downloaded on the pc, via USB cable. A first quick manual analysis was done in order to check the user annotation and find potential important mistakes (such as the user forgot to notify in the app that he has changed transportation mode). At the end of September 2016, 22 users have participated, generating about 40 Gigabytes, 400 files, and representing 217 hours.

Both prototypes operate by invoking a chain of four sub-services in the following order:

- “Sensor reading” that reads raw data of different sensors of the and store them into buffers.
- “Features”: computes some relevant features from the previous buffers
- “Classifier”: calls ***M*** classifier(s) (= algorithm) with in input a subset of the previous features and give ***M*** predictions of the transportation mode.
- “Post-Classify”: Fuses the ***M*** predictions into one unique prediction.

4.2.3 The Multi-objective Optimization Tools @SINTEF

This prototype is managed by SINTEF, in Oslo.

Objective: this prototype constitutes the core MOT module of BONVOYAGE.

Brief description: Various software components make up the MOT, and are under active development. Currently the array of software components is as follows:

- A **simple directory service** for the other services to find each other. This service will later in the project be replaced with an ICN service built on top of OGB.
- An **orchestrator service** that distributes routing requests to the individual routing services. This service is not fully operational, because further research and development activities from WP4 and WP6 are needed.
- A **routing service** hosting the routing algorithms. We already have an instance encapsulating/hosting the DYNAMO algorithm and another one hosting the Google routing service, thus proving that the concept of federation is feasible.
- A **demonstrator client** where we can produce route requests and receive and visualize the corresponding responses.
- A **service control panel** to launch services and see their statuses

Figure 9 below shows the MOT at work on a Grenoble-Bilbao request.

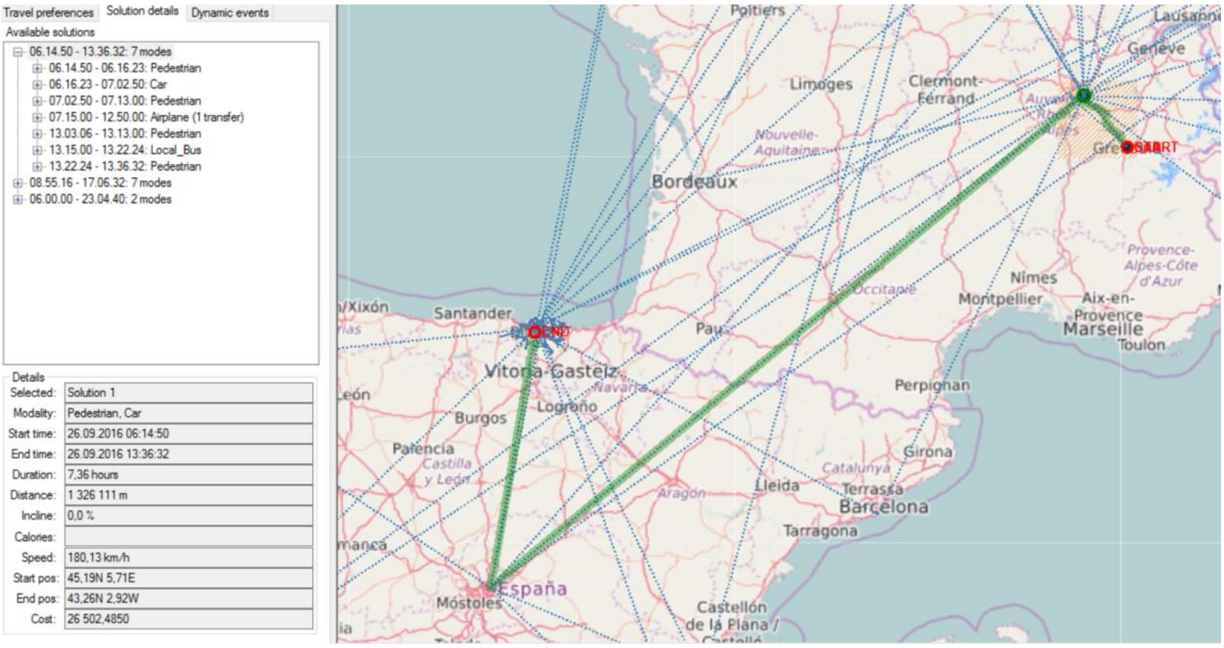


Figure 9: MOT at work on a Grenoble to Bilbao request

Routes from Grenoble to Bilbao are computed using car, public transport and flight networks and data coming from the following sources:

- Road data (Open street map)
- Public transport (GTFS – Bilbao local)
- Flights (QPX Express – only small extracts)

4.2.4 The urban soloist for car-pooling @CRAT

This prototype is managed by CRAT, in Rome.

Objective: This specific urban soloist is capable to offer carpooling in an urban road network and it easily integrates further transport modalities and smart mobility services.

Brief description: as shown in Figure 10, our urban soloist needs the following inputs to be initialized and to return optimal routes:

- Static input: all the data needed to set up the graph of the related area. These data are about the city map (streets, speed limits, road signs) and public transport infrastructures (stop locations, lines) and they change very slowly. For this reason, it is possible to consider them as static input for the algorithm and in BONVOYAGE it is possible to assume that they are updated periodically.

- Dynamic input: all the information that can change frequently as the traffic status, the public transport service availability, new ride-sharing offers and in general the detection of some event like accidents, strikes or breaks on public lines.
- Algorithm: a proper algorithm to solve the specific planning problem has to be selected.
- User query: this input represents the request of the user that want to find the best path according to his/her preferences on the graph built using static and dynamic inputs.

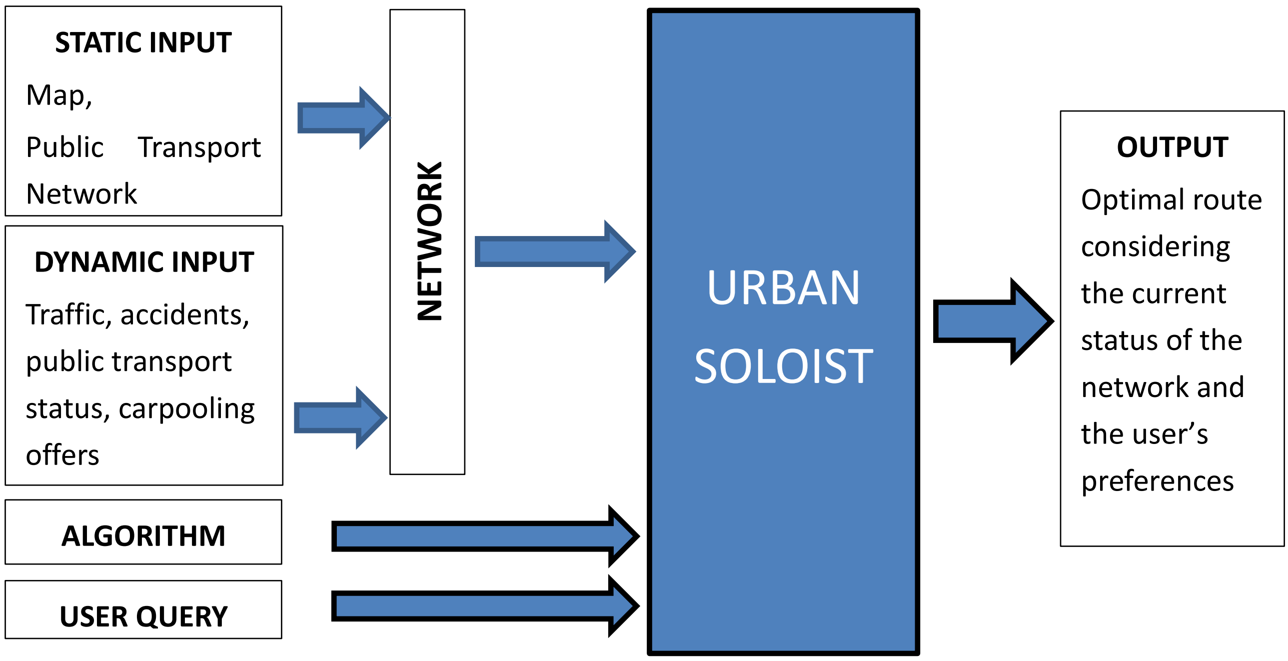


Figure 10: Urban soloist interactions

Static inputs are used to build the network that represents in a logical way the area covered by the urban soloist. In particular, the maps are downloaded from OpenStreetMap and the public transport infrastructures can be easily downloaded in GTFS format by using the OpenGeoBase of BONVOYAGE (exposed at bonvoyage2020.eu/travelcentricservices, see section 4.2.5).

For the purpose of the urban soloist, the transport network has been modelled as a multi-layered graph obtained as a superimposition of different layers, each one representing a transport means.

We provide an example of how the urban soloist is able to integrate the multi-modal trip planning with the car-pooling service. It is assumed that a user Alpha plans a trip from "Zamudio, Bilbao" to "Altzaga, Bilbao" for today at 19:00 pm, and the user intends to share the journey with other BONVOYAGE users. Figure 11 shows in red the itinerary that the user will follow with his/her car.

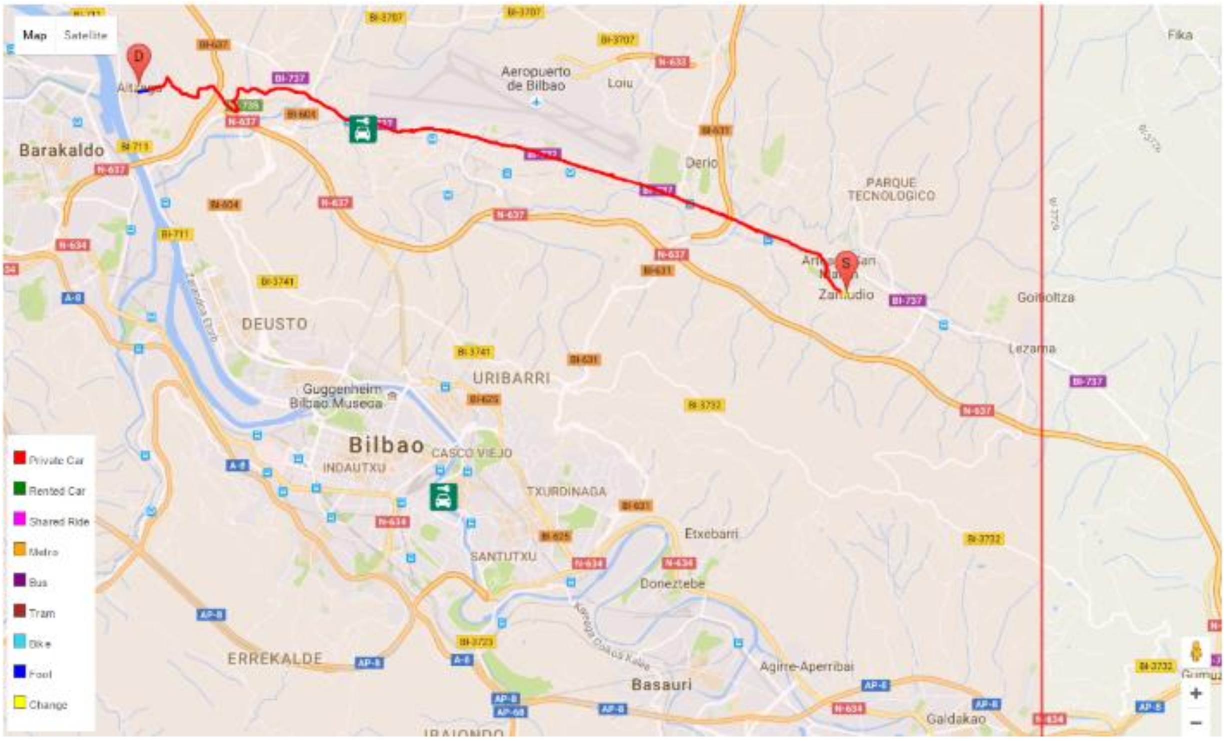


Figure 11: Car-pooling service: the driver shares a ride

Consider now that the orchestrator asks to the urban soloist to plan the journey for user Beta that intends to start at 18:50 pm from “Zamudio, Bilbao” (same source address of driver Alpha) and has to reach “Aeropuerto de Bilbao”. User Beta wants to search if exists some driver available to share an itinerary useful to get him closer to the airport. this case, the urban soloist will return to the orchestrator the solution reported in Figure 12, where Alpha and Beta shares the first part of the itinerary (highlighted in purple) and after Beta will reach the airport by walking (dark-blue path).

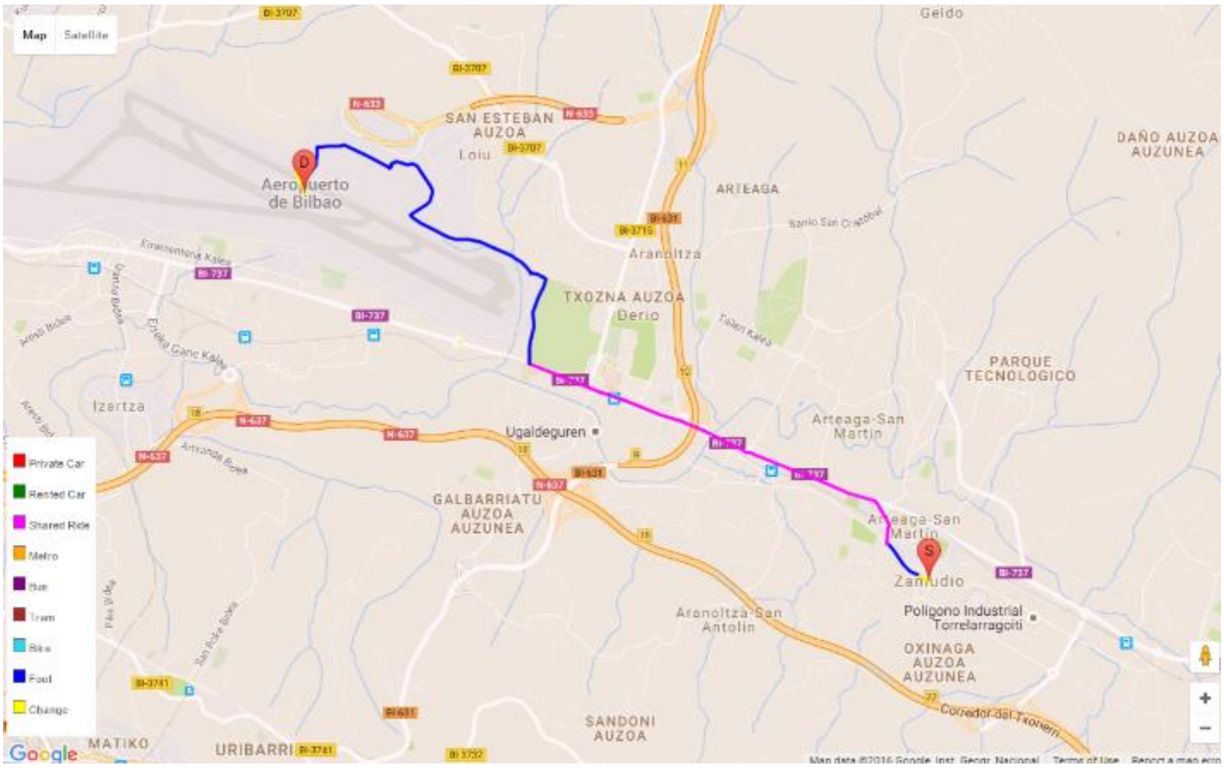


Figure 12: Car-pooling service: single source-multi destination solution example

Consider now a query coming from user Gamma that asks for a planning including all the available public transports and the car-pooling service. Gamma today at 19:00 pm should go from “Ola Bidea, Bilbao” to “Altzaga, Bilbao” using the bike or benefit from the car-pooling service. The urban soloist will return the solution shown in Figure 13, where Gamma reaches by bike Alpha (sky-blue path) in an intermediate node and then they will go to Altzaga sharing the ride.

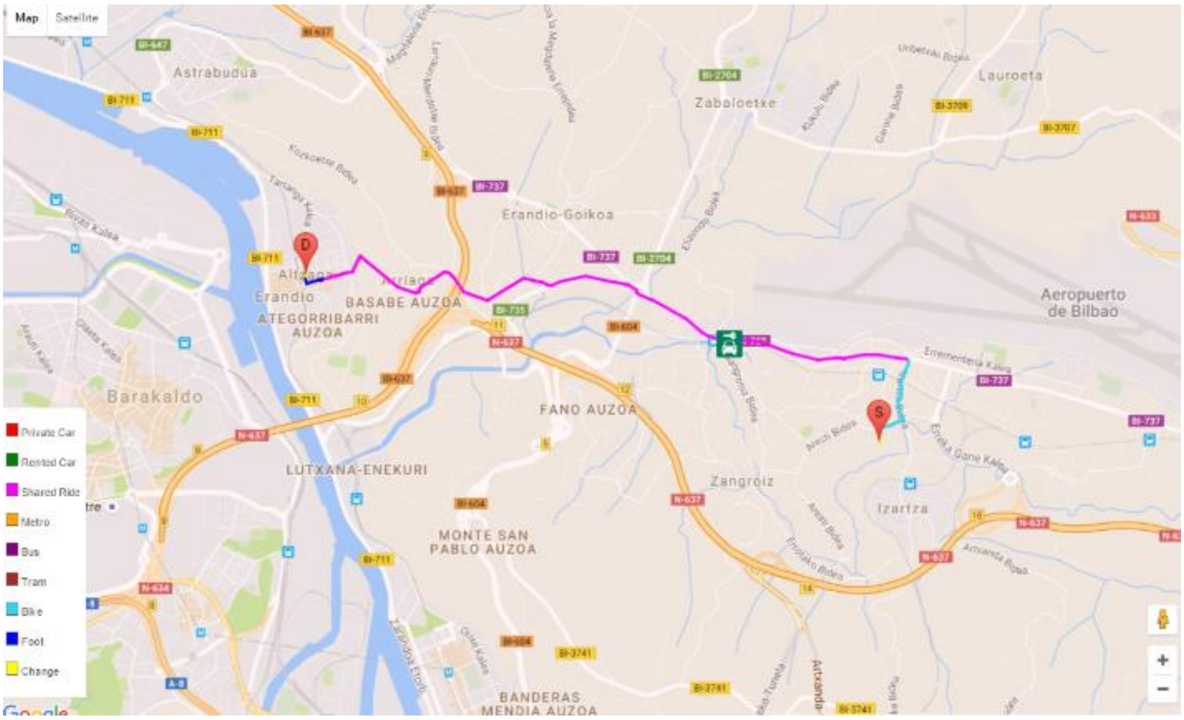


Figure 13: Car-pooling service: multi source-single destination solution example

Finally, in the case the orchestrator asks to the urban soloist to plan for the user Delta a trip from “Parque tecnologico, Bilbao” to “Indautxu, Bilbao” at 18:30, using only public transport and possibly the car pooling service as passanger, the subsolver will provide the solution shown in Figure 14, where passenger Delta goes by walk (dark-blue path) to an intermediate node where he will meet the driver Alpha and then they will reach togheter Altzaga (in purple is highlighted the polyline that join all the nodes visited by the car-pooling service). In the end, Beta will walk to the near subway station in Erandio and he/she will reach Santuxtu after six stops.

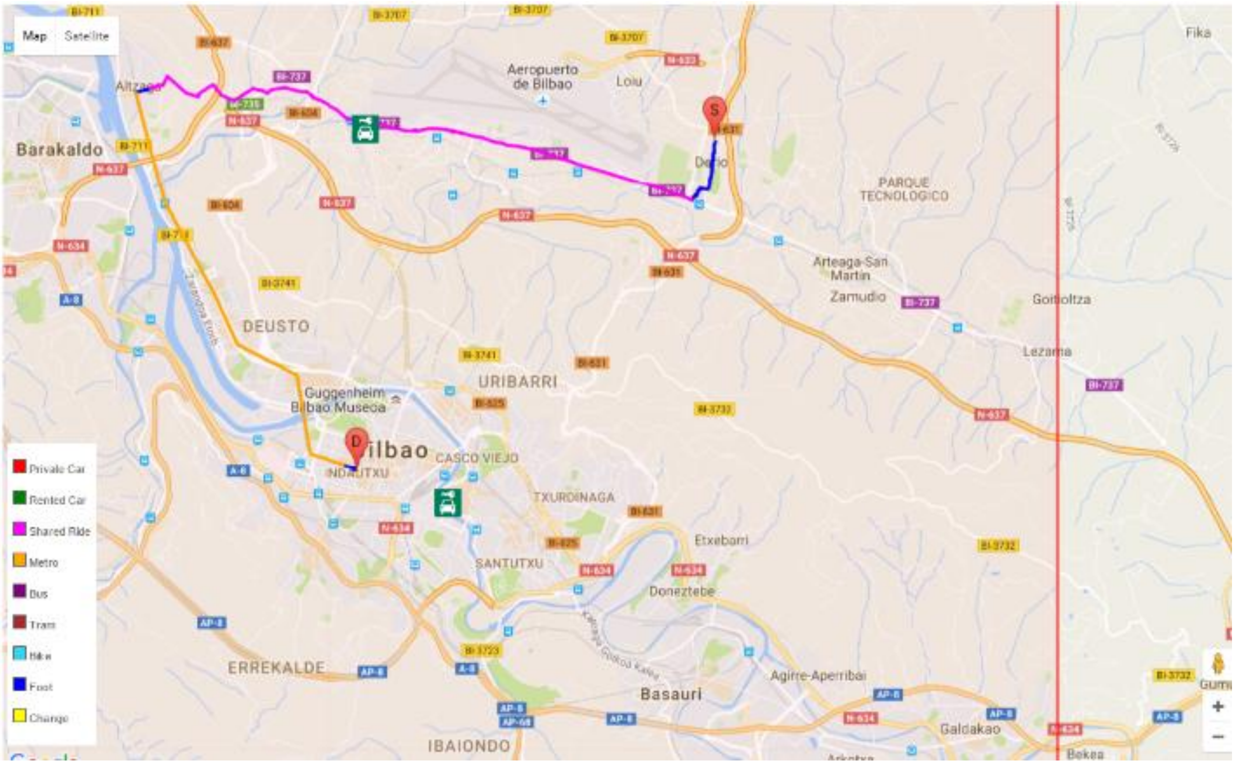


Figure 14: Car-pooling service: multi source-multi destination solution example

The car-pooling service integrated by the urban soloist allows to a passenger to take and leave a car in any intermediate node (including driver's source and destination) compatibly with the time needed to reach these nodes. Obviously not all the rides offered by drivers and useful for a passenger can be considered by the urban soloist: in fact, certain constraints as the availability of seats and concerning some special needs (e.g. handicap, extra luggage, animal) must meet between driver and passenger before to consider the ride as a 'candidate'.

The urban soloist includes also the possibility to share a ride added by a driver that will drive a rented car instead of a private car.

The testing phase of the urban soloist has been carried out using an Intel Core CPU i7-4710HQ 3.5 GHz, 16GB RAM computer, running MS Windows 10 Professional operating system has been used. The average execution time evaluated on five hundred random queries is about 400 milliseconds and it varies between a minimum of 350 milliseconds and a maximum of 500 milliseconds.

4.2.5 OpenGeoBase @CNIT

This prototype is managed by CRAT, in Rome.

Objective: discover information and data sources about travel that different providers offer within a specified geographical area.

Brief description: it is a discovery service of public transit data for software developers, transit agencies and more. The prototype is based on a multi-tenant distributed Discovery Service backend assigned to the "BONVOYAGE" tenant. Users (including Service Providers) can specify an area of interest (in terms of a GPS tile or other search criteria such as data type) and will get the URIs (HTTP and NDN) of the offered travel information. Users can then directly retrieve the data from the Transport Information Providers.

The backend of this prototype is based on OpenGeoBase: a distributed set of Sqlite3 database engines interconnected by the Internames Communication System of BONVOYAGE. Currently it has indexed about 1000 indexed GTFS files, retrieved from www.gtfs-data-exchange.com.

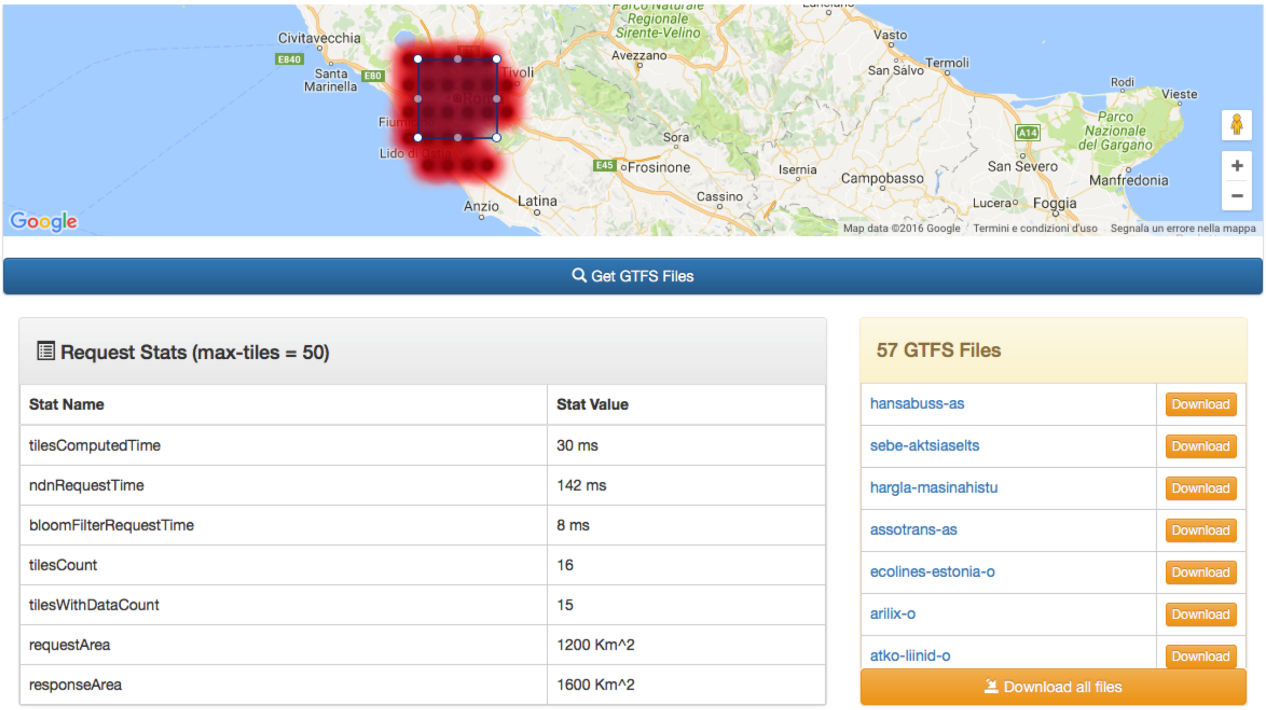


Figure 15: OpenGeoBase at work on a query around Rome

Figure 15 shows how OpenGeoBase responds to a query asking GTFS sources in an area of 1200 square kilometres.

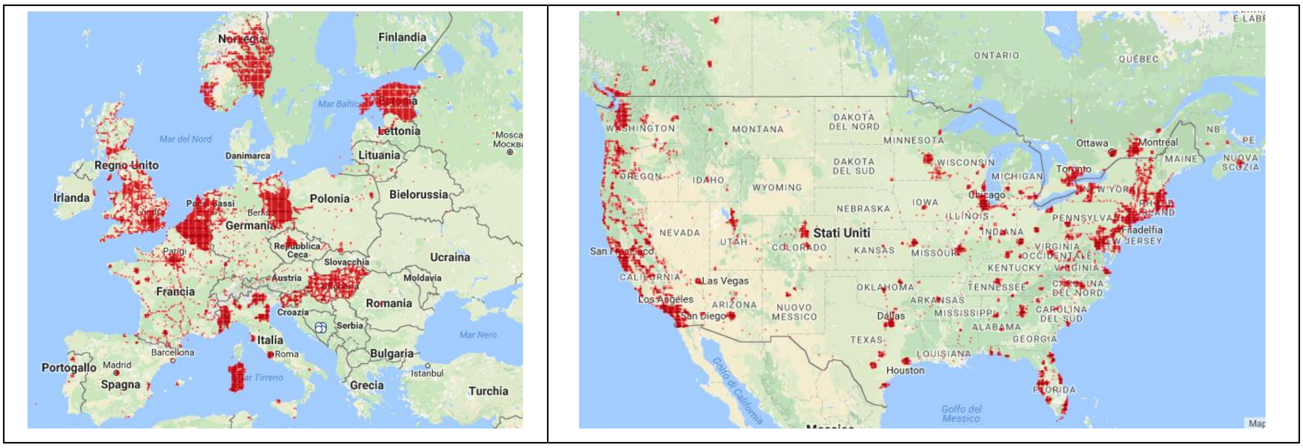


Figure 16: OpenGeoBase EU and US current coverage

Figure 16 shows current coverage of EU and US of OpenGeoBase, displayed as heat-maps.

4.2.6 Publish/Subscribe dissemination of real-time travel data @CNIT

This prototype is managed by CRAT, in Bari.

Objective: optimize the distribution of DATEX II real-time information through pub/sub.

Brief description: a user (for instance, a provider wanting to establish a novel ITS business) is able to receive continuous updates about real-time changes of select DATEX II information by: (a) selecting the area of interest; (b) obtaining a list of names; (c) making a subscription; (d) simply waiting for updates.

This prototype is able to simplify management of DATEX II data through pub-sub functionalities. Normal handling of DATEX II information from the NPRA server implies continuous download, processing, and selection of the whole huge, country-wide dataset.

The experimental testbed shown in Figure 17 takes an ICN approach to make distribution of travel data more efficient. A scenario was set-up where data crosses IP and NDN domains. Data source is the NPRA server at:

https://www.vegvesen.no/ws/no/vegvesen/veg/trafikkpublikasjon

Which includes:

- Road weather data: Data is automatically collected from 300 road weather stations along the national road network and include both observations and calculated predictions on certain routes.
- Travel times: Data is collected from AutoPASS OBUs and contain information about route, direction, time and present calculated travel time. Travel times are provided on main roads in Oslo, Bergen, Trondheim and Stavanger.

- CCTV (Closed circuit television): Images collected from a number of CCTV cameras along the national road network. Contain information about position, direction, time and a link to the CCTV image.
- Road and traffic information: Contain information about incidents, road works, road closures and driving conditions provided by 5 regional Traffic Information Centres.

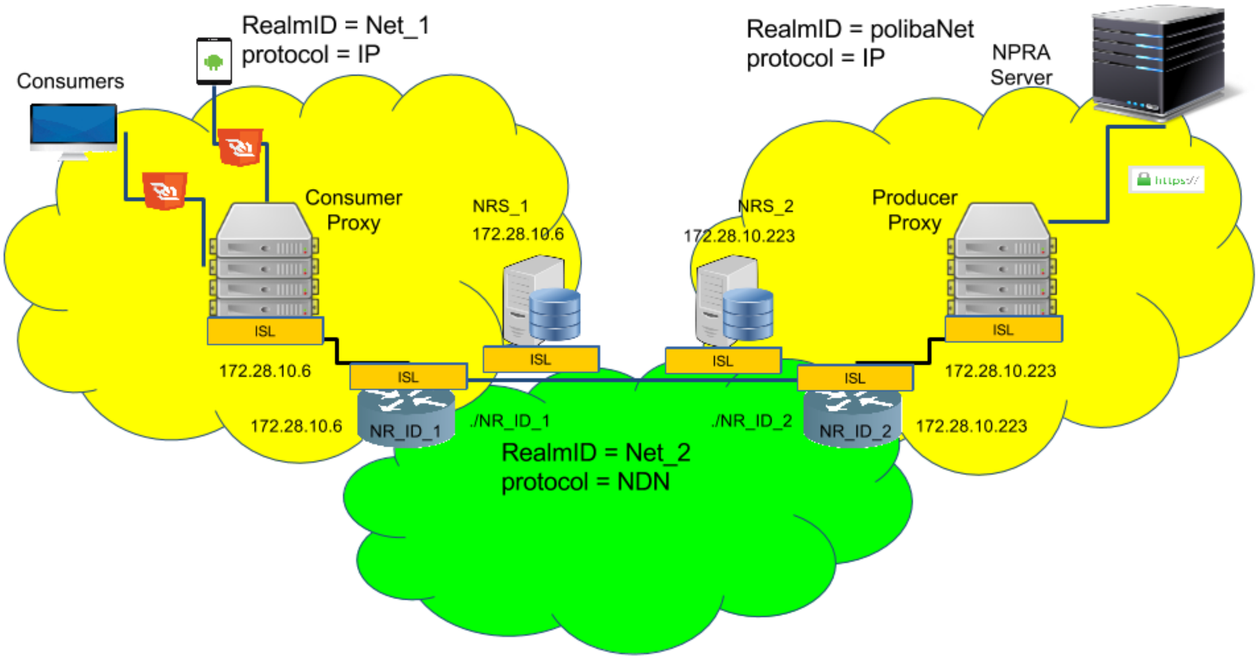


Figure 17: Pub/Sub testbed integrated with NPRA server

The prototype retrieves and then pushes to subscribers the travel-centric data and participatory sensing contents through request-response and publish-subscribe communication schemes over the heterogeneous network infrastructure. For example, the following name is automatically associated to a selected piece of information originated at NPRA:

n2n://polibaNet/bv/datexII/0758/40/GPS-ID/npra/cctv

It refers to the following naming structure, which is a realm-based, geo-referenced, hierarchical schema:

n2n://[realm ID]/bv/[standard]/[geo_info]/GPS-ID/<additional_info>

Any updates occurring to the selected piece of information (in the selected geographic area) are delivered to subscribers whenever a change occurs.

4.2.7 Green Score Policy @TRIT

This prototype is managed by TRIT, in Rome.

Objective: influence users mobility choices with the ultimate goal to reduce the environmental impact of the travel solutions selected by the users, pushing them to select travel solutions composed of means of transport with a low level of CO_2 consumption.

Brief description: scores are assigned on the basis of the means of transport selected by the users and user has the possibility to use the scores to obtain prizes, awards and discounts.

Score is assigned to users if there is the **availability of at least 2 possible alternative travel solutions** to cover the itinerary (point of origin - point of destination).

User's mobility behaviour is evaluated in two time periods:

- **At Time 0 (T0)**: user eco-friendliness level is not defined. Score is assigned to all users based on the same rules.
- **At Time 1 (T1)**: on the basis of the travel solutions and related means of transport selected by the user in T0, users eco-friendliness level is defined and users are distinguished into 4 different clusters (*User Eco-friendliness Profile*):
  - ***Eco-friendly User:*** user that chose between 76% - 100% of times the lowest CO_2 consumption travel solution;
  - ***Quite Eco-friendly User****:* user that chose between 51% - 75% of times the lowest CO_2 consumption travel solution;
  - ***Low Eco-friendly User****:* user that chose between 26% - 50% of times the lowest CO_2 consumption travel solution;
  - ***Not Eco-friendly User*****:** user who chose between 0% - 25% of times the lowest CO_2 consumption travel solution.

The definition of the "User Eco-friendliness Profile", that entails the transition from Time 0 and Time 1, takes place after a pre-set number of travel solutions chosen by the users.

The number of the travel solutions after which "User Eco-friendliness Profile" is defined depends on the users travel frequency. Three different groups were defined on the basis of the travel frequency:

- **Occasional Travellers**: users who travel occasionally, for several reasons (e.g. pleasure trips, holidays or special events). For this group, User Eco-friendliness Profile is defined after 20 travel solutions selected by the user.
- **Periodic Travellers**: users who periodically travel for personal and / or working reasons (e.g. users who work away from home and come back for the weekend; users who like to travel for pleasure 1/2 times per week). For this group, User Eco-friendliness Profile is defined after 30 travel solutions selected by the user.

- **Frequent Travellers**: users who travel a lot for personal and / or working reasons (e.g. business travellers who have to go to work every day). For this group, User Eco-friendliness Profile is defined after 60 travel solutions selected by the user.

The number of travel solutions after which the User Eco-friendliness Profile is defined is:

- lower for users who travel less frequently, since they need more time to reach a threshold of travel solutions that enable to profile them;
- higher for those who travel more frequently because, as opposed to the first, they need less time to achieve an adequate number of travel solutions to be profiled.

4.2.8 Tariff Scheme design @CRAT

This prototype is managed by CRAT, in Rome.

Objective: The algorithm designs pricing rules that allow the transport operators that build the partnership to increase their profits; (ii) benefit passengers and (iii) reduce pollution.

Brief description: the prototype helps designing tariff schemes for multi-modal long-distance trips operated by a partnership between air transport and high-speed rail (hereafter, HSR).

In the following example we show how the prototype works on an exemplary route: Nantes-Saint Marteen. The baseline story is that Maria has to go from Nantes (rue Adolphe Moitiè, 19) to Philipsburg (Soualiga Road, 60). She is travelling for leisure purpose. She does not want to have more than one stop. Thus, she has two options:

1) Air France flight. This is a one-stop flight. Maria leaves from Nantes Atlantique Airport (NTE) and takes a flight towards Paris Charles De Gaulle Airport (CDG). Here she connects to a flight towards Princess Juliana International Airport (SXM).

Importantly, Maria does not want to switch from one airport to another one, when she has to make the interchange (i.e., the alternative in which Maria lands in Paris Orly, transfer to Paris Charles De Gaulle and then she takes the long distance flight, is not a feasible alternative).

2) TGVAir product offered by SNCF-Air France. This is a combined air-rail ticket. Maria leaves from Gare de Nantes (QJZ) and takes a high-speed ride towards Paris Charles De Gaulle Airport. The ride is offered by SNCF (Societè Nationale des Chemines Francaises); once in Paris Charles De Gaulle Airport, she takes the flight towards Princess Juliana International Airport.

On the network, there are other people travelling from Nantes to Paris. They have two options:

1) Air France flight. This is a direct flight. People leave from Nantes Atlantique Airport and take a flight towards Paris Charles De Gaulle Airport.

2) **High-speed rail ride**. People leave from Gare de Nantes and take a ride towards Gare de Paris Montparnasse. The ride is offered by SNCF

Moreover, there are other people travelling from Paris to Philipsburg. They have one option: taking a direct flight from Paris Charles de Gaulle to Princess Juliana International Airport.

In this framework, Air France must decide how much should Maria be charged on the connecting flight or on the TGVAir product.

Benchmark scenario: The airline and the HSR are pure competitors. Only air transport is able to operate the route A-B. There is no partnership between air and rail and the two transport operators maximize their profits simultaneously and separately (*Cournot Nash competition)*.

Partnership scenario**:** The airline and HSR form a partnership to operate market AB, involving integrating tickets, coordinating schedules, providing connections between airports and train stations and possibly streamlining baggage transfer or other valuable services (i.e., that increase relevant dimensions of quality identified in the survey). The partnership between the two modes can increase significantly the attractiveness of the air-rail product and travellers may consider it as a valid alternative compared to the connecting flight. In particular, we assume that the partnership is implemented through a vertical agreement. In other words, we assume that, first, the HSR operator sells seats on the train to the airline at a charge w; second, the airline decides how many seats to buy on the HSR train, and then sells a coordinated train-plane product in market AB (two-stage game).

As a baseline, operators should enable passengers to purchase a single ticket for the entire multimodal trip. In such a case, the airline and the HSR operator decide to share the same trip, and each operator can mark each segment of the journey with its own code, independent of whether the airline or the HSR is actually operating the service. This requires operators to integrate their information technology and computer reservation systems. More importantly, it requires operators to coordinate schedules between air and HSR services. In doing so, operators decide to take the risk associated with possible delays on one segment of the journey, and provide passengers with proper warranties. Operators can also consider offering coordinated baggage handling (so that passengers should not care about baggage transfer at the intermediate stop), and/or supplementary services on HSR trains similar to those offered on short-haul flights (e.g., dining).

We evaluate:

The profitability of the partnership: the transport operators will decide to build the partnership if and only if incremental profits gained are positive, net the (fixed) costs that would arise if they build the partnership, for the airline and the HSR respectively.

<u>**The effect on prices**:</u> if the partnership is built (i.e., there exists a *two-stage Nash equilibrium*) we provide resulting optimal prices for each leg.

Otherwise, if there exists an operator which has no incentive to build the partnership, we show which operator is losing money.

4.3 Scientific and Technological impact

At the time of writing it is rather early to assess BONVOYAGE impact; thus, this section and the two following ones will be suitably expanded in the next version of this document. However, the work performed during the first year produced some visible and tangible results.

As regards scientific publications, BONVOYAGE is targeting top tier research conferences and journals. These leading venues shape future research in this area and as such provide maximum visibility for the project results. Several partners have an established presence and a strong track record in such venues.

The current list of publications is reported in http://bonvoyage2020.eu/results/dissemination.

Another important activity to exert impact is of course standards. Standards are a key way of ensuring that BONVOYAGE has a real impact. The standards process distils the best technical approach, as well as helping to ensure interoperability.

The BONVOYAGE project has been presented by CNIT at the interim meeting of the ICN Research Group (ICNRG) during the last IETF 93 meeting, held in Prague by Prof. Alfredo Grieco from CNIT. The target of the presentation was to illustrate the potential of the project as a framework to define vertical use cases on top of ICN communication technologies.

The key concepts related to the Internames technology in BONVOYAGE have been also included in ad hoc standardization documents (IRTF Drafts) focusing on open challenges and middleware ICN-IoT architectures.

The partners interested in working on standards and contributing in their development are:

- CNIT: the CNIT Research Unit from POLIBA is strongly committed in contributing in IRTF and IETF. Articles in scientific journals have been issued, as described in the previous paragraph, and several articles are under preparation and publication.
- SINTEF: SINTEF intends to participate to the DATEX II forum and contribute to the standard. Indeed, one weakness of the current standard is the lack of information which can be easily exploited by routing algorithm. SINTEF intends to contribute to these aspects by proposing suitable extensions to the standard.

4.4 Market impact

At the time of writing, there are no products that have been developed that benefit from BONVOYAGE. Based on events and discussions there would appear to be a high interest in the potential outcomes of BONVOYAGE. Most of the prototypes are tied in with expected commercial needs of the partners involved in those prototypes and as such it is expected that in the revision of this document there will be a significant change in this section. In the research field, the papers that have been submitted have had an impact in their relevant areas, with some of the challenges posed providing new areas for investigation.

4.5 Societal Impact

At the time of writing it is too early to provide measurable results on the societal impact.