Comparison of Historical and Physical Models to Predict Marginal Electricity in the Context of Cloud Optimization

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Abstract. This paper is an abstract for a *poster* submission for the EAI International Conference on Smart Sustainable City Technologies.

Keywords: Life cycle assessment · Electricity · Data centers

1 Introduction

The ICT sector is growing really fast. To keep up with the ever-increasing need for storage and computation power, companies are building an increasing number of data centres. These data centres require a lot of energy (1.3 % of world electricity in 2010 [1]) to supply power to the servers but also to their cooling systems. This growing demand for energy is becoming an environmental issue. Indeed, the ICT sector was reported, in 2007, to emit 2 % of anthropogenic greenhouse gas emissions (GHG) [2]. For that reason, important efforts are being made to improve energy efficiency of data centres and supply them with low carbon energy.

One reason explaining the need for additional computation power is the emergence of smart technologies. This is especially the case of smart cities that are anticipated to generate a constant flow of data that need to be processed continuously. Indeed, the key component of smart cities is the ability to analyze information in order to make the best decisions for the urban environment in real time. This is now possible thanks to new technologies that enable to collect, transmit, centralize, store and process data.

One idea to reduce the environmental impacts of data centers is to have multiple data centres in different regions and use the one located in the region with the cleanest electric grid mix at anytime. While this approach requires virtual servers migrations it has a great potential for reducing GHG emissions and other environmental impacts. In recent projects, the life cycle assessment methodology has been used to produce environmental indicators for ICT systems [3, 4]. Life cycle assessment (LCA) is a tool to quantify the potential environmental impacts

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of a product, a service or a policy. The strength of LCA is that it considers several environmental indicators (not just carbon or GHG emissions) and includes all the life cycle stages of projects. Thus, LCA has the ability to catch environmental impact displacement that occur when a life cycle step is improved while another one is deteriorated. However, current modeling of the electricity generation in LCA may lead to biased results. Indeed, in LCA, impacts of regional electric grid mixes are currently computed with yearly production averages. Therefore, from an LCA perspective, the impacts of 1 kWh are the same all year long. In the real world, the mix of the different technologies used to generate electricity changes all the time, depending on the demand, weather, maintenance, etc. This major difference with reality prevents LCA from correctly evaluating the impacts of a technology with a very fluctuating demand for electricity such as ICT. This is even more true when the electricity consumption of this technology is being optimized like in multi regional data centres management approaches. To overcome this issue, temporally disaggregated data of electricity generation were introduced in consequential LCA to build prediction models [4]. Based on historical data of electricity generation in multiple regions of Canada, these historical models were implemented in a Green Sustainable Telco Cloud to minimize GHG emissions by identifying in real-time where the cleanest electricity would be available.

However, these prediction models do not include physical limitations and parameters of the actual electric grids. Adding a significant power demand by turning on a data centre will require a new balance of the grid that is expected t depend on the geographical location and the amplitude of the power demand. If confirmed, the location of the data centre inside a region could also be considered as a parameter of global optimization of the data centre deployment. By producing a simplified model of the Ontario electric grid, it is possible to test if the required electricity to supply the additional power demand of a data centre in Ontario matches the prediction of the historical model previously developed. It is expected that the physical parameters such as the load capacity of lines, geographical disposition or reserve capacity will have consequences on the selection of the marginal sources of electricity that will meet the power demand of the data centre. Therefore, it is anticipated that in a few cases, the historical model might identify marginal electricity that is not available at a given time. Introducing physical constraints to the historical model will help to improve it.

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How to Address Behavioral Issues in the Environmental Assessment of Complex Systems: Case of a Smart Building

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Abstract. The life cycle assessment of complex systems such as smart-buildings requires taking into considerations rebound effects caused by human behaviors. This project aims at modelling rebound effects with an agent based model using human behavior theories.

Keywords: Life cycle assessment · Human behaviors · Agent based model · Smart building

1 Introduction

Information and communication technologies (ICT) are believed to possess the potential to reduce greenhouse gases emissions (GHG). Their application to the residential sector – which is responsible for 30 % of global GHG – has aroused numbers of initiatives around the world, at smart-building, smart grid, and smart city levels. The common goal of these initiatives is to help achieving sustainability through energy consumption reduction.

One of these initiatives is the new student dormitory of Ecole de Technologie Supérieure (ETS) in Montreal. The project aims at making the dormitory "smart" by allowing household appliances and systems to be controlled automatically by a mobile cloud of machine to machine (M2M) smart objects.

2 Research Problem

Although reduction of environmental impacts was made possible thanks to virtualization of services and activities, it is stressed by several authors that those benefits might be partially offset by a phenomenon called the "rebound effect" [1]. A good example of rebound effect is teleworking: while a direct positive environmental impact

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of working from home part time is a decrease in the need to drive to the workplace, an indirect negative effect can occur if that reduction in the number of commutes is the reason why the household decides to live further from the workplace. In other words, the environmental benefits of part time teleworking may be partially offset by the increased distance between the home and the workplace.

Therefore it is argued that environmental studies of ICT should not be only focused on the technology itself, but also on its utilization. The goal of this project's research is to specifically address the issue of rebound effects on building users when evaluating the environmental impacts of ETS's smart building.

3 Methodology

The approach will use agent-based modeling of the users combined with life cycle assessment (LCA) in order to account for occupants' behaviors in the environmental assessment of the smart building. Agent Based Modelling (ABM) is a technique that has already proved useful for the LCA of complex systems such as biofuel production [2].

This project will use existing theories on consumers behaviors to identify the main variables explaining the choices of an individual regarding the utilization of ICT [3]. Once those variables are well-defined and comforted by a field study, they will be incorporated in an ABM. The model will be built in order to predict the electric consumption of the smart building mentioned above as a function of the values taken by the behavioral variables. Once the consumptions are computed, an LCA will transduce them into impacts. The model will be confronted to the real time data from the smart-building, and optimized to improve the accuracy of the prediction. Finally the ABM will be used to study different scenarios using hypothesis on the behavioral variables.

4 Outcomes

The project will both answer ICT system designers who need to know how their technology is effectively used, as well as address methodological issues currently faced by LCA practitioners regarding sustainable consumption and rebound effects. Finally the methodology developed in this project will be applied to study the expected environmental performance of a smart city.

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A Novel Approach to Enabling Sustainable Actions in the Context of Smart House/Smart City Verticals Using Autonomous, Cloud-Enabled Smart Agents

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Abstract. This poster presents a practical application of ICT agents in a use case of smart houses. The proposed solution provides a certain level of accountability from every house. Many resources that the agents may require, such as data storage or specialized analytics, is hosted on high-performance cloud-oriented data and compute centers, such as that of Green Sustainable Telco-grade Clouds (GSTCs).

Keywords: Sustainability · ICT · Smart house · Agents

1 Extended Abstract

Along the global shift from products to services and as a step further, the Information and Communication Technology (ICT) services are replacements for many 'material'-driven services. Considering the limited amount of [natural] resources and also the additional energy and water used in the manufacturing of the material-based products and services, ICT services have a great potential to serve as a 'platform' to transform the world toward dematerialization. However, a non-sustainable ICT would itself cause more damage than benefits. Therefore, the sustainability requirements should cover all elements and components of any ICT solution, for example data centers, network and equipment, in order to ensure a large scale adoption of ICT across the globe. One approach to reduce the possible risk and impact of the complexity on the performance and also sustainability of an ICT solution is shifting toward non-centralized ICT. Non-centralized ICT in particular put an ICT footprint on the customer premises beyond just a user interface, sensor, or actuator. To put more emphasis on this aspect, we introduced the notion of (E)ICT, which stands for (Embedded) Information and Communication Technology, to highlight the importance of embedded parts of any ICT solution. The power of ICT in enabling real-time, long-distance, networked interactions and communications has nominated it an enabler and also a carrier of various disruptive changes for good. This particularly is very important in the context of cities and urban living. As mentioned before, all these benefits could be jeopardized by a non-sustainable

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operation of ICT itself. All ICT equipment passes through a complicated path of manufacturing and fabrication along which rare, conflicted minerals and other expensive material are used to build the final equipment. Although a big impact associated to equipment is the energy consumed and the associated GHG emissions, there are other environmental impacts such as those related to toxic material that should be considered in the assessment of sustainability of an ICT solution. Single-goaled visions to ICT for sustainability, such as that focusing only to reduce the GHG emissions, would cause more problems, especially those related to health and wellness. Therefore, Life Cycle Assessment (LCA) of the operation is required to contain all impacts and footprint. There is also an ever increasing growth in the integration of Internet of Things (IoT) and low-cost, low-power sensors in all aspects of life. Although we are far from reaching a technological singularity, the current state of available artificial intelligence and also real-time communications have great potentials to take over a large portion of the workloads especially those related to undesired, undignified tasks.

This poster presents a practical application of ICT agents in a use case of smart houses, where federal regulators govern services of a household particularly in relations with external entities such as utilities. There are various resource flows to a typical household, such as Water, Electricity, Data, Food, and Air (WEDFA) flows, which are highly critical from the sustainability perspective at both local and global levels. Therefore, smart-house solutions have a great potential in reducing not only the primary resource consumptions at a household, they also could minimize secondary, associated resource consumptions occurring within operation and maintenance activities of the utilities. Although deployment of sensing devices and continuous monitoring has been a trend in implementation of generic smart house solutions, there are several concerns that could delay or jeopardize massive adoption of these solutions, particularly the risk factors related to privacy and security along with other concerns related to rapid increase in the number of vendors.

The proposed autonomous, cloud-enabled, agent-based smart house is a potential solution to this chaotic situation. The agent(s), which operate on the house side, control all outgoing data and also all ingoing commands. The generic nature of such an agent, which we call a Federal SmartHouse Regulator, makes it highly compatible with open source and crowd-based paradigms, which increase trust and also pace of development. These federal regulator may govern every service interaction related to a vendor's sensor/actuator, and also may create their own interactions with counterpart agents of the high-level entities, such as those of the utilities, in order to reduce the resource consumption while providing a high-quality experience to the residence along with generating 'value' for them. The main role of these agents is in providing a certain level of accountability from every house which in turn reduces a big amount of uncertainty in capacity planning on the utilities side. Although the intelligence of every agent is recommended to stay within the actual premises of their associated entity, many of the resources that the agents may require, such as data storage or specialized analytics, is hosted on high-performance cloud-oriented data and compute centers, such as that of Green Sustainable Telco-grade Clouds (GSTCs). This is an example of how ICT and its associated services could serve as a dynamic platform for reaching a true realization of networked society where every person and industry is empowered to reach their full potential.

Resource Consumption Assessment for Cloud Middleware

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1 Introduction

To provide users with relevant information about cloud operation and to be aware of cloud performance, it is essential to understand the cloud system behaviour and analyse the performance of cloud components to pinpoint on its strength and limitations. Infrastructure as Service (IaaS) allows a vision for acquisition and management of physical resources and the elastically, and is expendable to users to add more resources based on immediate needs. This way makes IaaS suitable for companies to deploy and configure their own private Cloud. Some open-source used for private cloud are Nimbus, Eculyptus, OpenStack and others. Facing increasing resource demand, Cloud administrator may either over-provision his cloud or reject a larger portion of requests (which is no longer on-demand). To better afford this kind of user requests a profiling phase is needed to seek which part of code or program uses most resources. Furthermore, this solution helps the administrator support his stack by learning more about his code. It provides an overview of each use case, gives an idea what are strength, leaking and bottleneck parts in order to intervene when it is required. However, a majority of prior research in the field were focused on only on high level, e.g. application layer which is built on the top of architecture models by analysing and monitoring applications performance, using multiple metrics like I/O, CPU, RAM, energy consumption and others. In the application layer, prior work has taken several approaches like instrumenting code, inferring the abnormal behaviour from history logs. In this paper, we investigate the relationship between resource usage and Cloud Middleware performance (OpenStack as an example), which runs in a dedicated server, also to determine the maximal number of instances that could be supported by the stack, and study the impact of those instances on resource usage. It would be beneficial to improve performance prediction and evaluate the success rate of user requests in order to make decision to accept or refuse a user request.

2 Methodology

To overcome this issue, we need to build a deep measurement and profiling framework for private cloud to determine the limitations and strength before using it

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in a production chain. We profile OpenStack based on various scenarios to determine the behavior of OpenStack components and to evaluate its performance. We address two questions typically for cloud middleware performance: (i) what is the hottest processes or code region influence on middleware performance?, (ii) how does performance vary regarding different amount of workflow? A number of metrics is considered like number of tenants, number of users per tenant, number of VM, VM image, and VM flavor, which will affect the performance of Cloud Middleware. Experimental design concept, especially factorial technique helps determine which of those metrics influences most on the performance of Cloud Middleware, and then pinpoints limitations and learns how CPU and Program Execution Time (PET) response varies on different amount of load. Our main scenario is to create and delete instances concurrently by creating a number of instances in parallel in order to stretch our stack to maximum and to observe how OpenStack will response. We used Rally as tool for benchmarking. For a given test, we change workload and run it for couple of times (to validate our results). The resulting performance enables us to establish links between the Cloud Middleware metrics and resource usage. This experiment determines the success rate and pinpoints the relationship between cloud Middleware metrics in terms of the successful rate of scenarios with data load variation. The response variable is measured by the success rate in each scenario. For instance, a scenario is defined to create a number of instances and then delete them after building them up (ready to use) and spread those instances on multiple tenants and users. To highlight the bottlenecks and limitation of Cloud Middleware. We simulate a real operational scenario by creating instances and then deleting them after having used. We consider the success rate as the output of the process and the input is (concurrency, tenant, users). Data is then collected to perform a statistical analysis in order to determine the effects of the main factors, and their interactions with the dependent variable (the success rate). We aim to extract the most significant factor(s), determine the relationship between significant main factor(s) and/or interactions and their impact on resource usage using a regression method.

3 Results and Conclusions

Our experiments showed that changing OpenStack configurations can support a larger workload up to 800 instances. The performance of OpenStack is controllable by three metrics which are correlated: the number of compute nodes, the number of running instances, and the number of workers across the Nova Cloud Controller. Also, resources consumed by OpenStack in terms of CPU increase along with the number of instances. The current version of OpenStack cannot support more than 800 instances, and the time required for creating instances increases linearly with the number of instances. In future work, we plan to use XEN and KVM virtualizations in parallel and compare their results obtained with XEN results especially for PTE and CPU load consumption.

Session Based Communication for Vital Machine to Machine Applications

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1 Introduction

Today, machine-to-machine (M2M) communication is often implemented in the telecom world based on a push and pull mechanism where devices push data to a central database and authorized services retrieve data when they need. There is no stream-oriented mechanism for M2M, which is required by a new class of critical and vital applications such as security monitoring, health and life monitoring, real-time recognition, etc. All these applications need a stream-oriented protocol that is controllable, monitored and secured. In addition, M2M requires an agnostic wide area network (WAN) that receives connections from different underlying access technologies, such as wired or wireless access. Such a network should be provided with a scalable addressing scheme which is auto configured when devices are deployed on the field.

Some previously proposed solutions offered IP Multimedia Subsystem (IMS) oriented connectivity, which reuse IMS sessions to connect devices together. These solutions deal partially with the general M2M communication problem by creating a session-based communication but do not really address the aforementioned concerns.

This poster presents a Machine-to-Machine Session Based Communication (MSBC) architecture that provides Telco-grade stream-oriented communications for critical applications and offers security, reliability, network agnostic and scalable addressing scheme.

2 MSBC Architecture

The proposed solution is a multi-tier architecture, composed of three main components: the local gateway (LGW) on the local domain, the M2M Interconnect Server (M2M-IS) in the operator's IMS core and the application service gateway (ASGW) in the M2M services provider domain. We define Connected Thing Identifier (CTID) as a serial number, MAC address or any agreed identity mechanism, which is basically the only identifier recognized in the MSBC network and used not only for getting addressed as destination but for addressing their counterpart on the network as the source of

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information. Routing in this network is done via a logical link, called wire, which is a virtual connection between one device and one application server. Such mechanism removes coupling between devices and the application server, exempting the need of network addressing configurations on the devices and the LGW, and so enabling massive deployment of machines.

The MSBC reuses the IMS core with an add-on of an extra service, called the M2M Interconnect Server, which is designed to be deployed in the service layer of an IMS network. It limits the impacts and facilitates the integration on operator's network, and at the same time, it inherits the network agnostic characteristic of the IMS service layer. The deployment process of MSBC, is to find an operator with a configured IMS architecture, add the M2M-IS node, and create subscribers in the operator's HSS with the address of M2M-IS configured by the service trigger.

Communication between components in the MSBC is done through MSRP, which is a de facto stream oriented payload protocol for messaging in IMS and 4G networks. MSRP is a reliable protocol, and secured when using MSRP over TLS. It also offers a reporting mechanism ensuring all the messages were received correctly.

As MSBC is builds on top of IMS, it is network agnostic. As long as you can reach the IMS core, you are able to use the MSBC features. Based on network access technology different behavior can be applied. In case of radio access, communication is encrypted by the underlying network, thus there is no need to encrypt MSRP with TLS. However, in case of local cable access, such precaution needs to be taken. On the other hand, local cable access offers almost free bandwidth compared to radio access, thus more data can be sent, including bandwidth-greedy unimportant updates that were held in standby.

MSBC would therefore be a strategic asset for operators, and even if it could be deployed as an Over the Top service, it will rely on the underlying operator's network to provide QoS avoiding suffer from best effort Internet access. Together with security requirements, the implicit operator's security measures in their access network optimize resource consumption of the explicit TLS fallback mechanism while performing on a public IP connection. Therefore, the MSBC is a more suitable solution for an operator's already enabled IMS network.

3 Experimental Results and Conclusion

A test environment was to simulate the implementation of a real-life use case consisting in a Play Mobil dollhouse where we have added some sensors, motors, actuators and other smart objects. There are 5 service providers; each offers a service to the smart house. Each service comes with some devices. All communication between the devices and the service providers is done via the MSBC's network. Six test scenarios have been carried out: Add/Remove CT; Transmission of data on existing wire; Clean shutdown; Lost connectivity – Watchdog; Switch between LTE and Wi-Fi; Swap from one AS to another (easy migration service provider).

We observed that the MSBC prototype addresses the needs for M2M communication. Furthermore, network agnosticity and addressing capabilities will provide a scalable, secure and efficient solution.

The first version of MSBC has been designed for a traditional deployment of IMS services, but today's technologies evolution challenges this implementation of services as a shortsighted view, and opens the question of what native cloud deployment services are optimal for MSBC. This evolution has been introduced on the MSBC roadmap and will be part of our future work.

Optimization of Energy Consumption in Smart Homes: A New LCA-Based Demand Side Management Program

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Abstract. Smart technologies provide new alternatives for sustainability. Forthcoming cities will gather innovations through buildings and grids among others. In the new dormitory of the École de Technologie Supérieure of Montréal, life cycle assessment (LCA) of electricity use measures the relevance of modern demand side management programs (DSM). Subsequently, an environmental indicator is established which provides a more comprehensive and sustainable solution.

Keywords: LCA · Carbon emissions · Electricity generation · DSM

European policies aim at reducing greenhouse gas emissions by 20 % while increasing energy efficiency by 20 % by 2020 and the household sector is believed to have a major role to play in reaching this goal [1]. Accordingly, new solutions for private homes based on information and communication technologies (ICT) are being developed to create smart technologies such as smart buildings or smart grids. This is the case of the new dormitory of the École de Technologie Supérieure of Montréal which will allow household appliances and systems to be controlled automatically by producing a mobile cloud of machine-to-machine (M2M) smart objects. The objectives of this smart home are to increase home automation, facilitate energy management and reduce environmental emissions over the entire building life cycle. Such a building would be efficient through the use of demand-side management (DSM) programs and the deployment of an energy management system (EMS) connected to a smart grid [2].

One of the main objectives of this research is to design a sustainable smart city model for an urban community based on the optimization of the energy consumption through a new kind of DSM focused on an environmental indicator.

DSM is a portfolio of measures that aims to improve the energy system as a whole by reducing the system demand when the supply becomes scarce. Two common DSM programs are currently popular; energy conservation and efficiency programs that intend to preserve energy and Demand/Load response programs [3]. The second strategy uses tools based on dynamic time pricing or time-of-use rates exposed to customers, which allow them to shift their energy usage from high-priced to low-priced periods [4]. But could we know the quality of the electricity consumed if only the price

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is regarded as the decisional factor? Admittedly, the use of the load as an additional degree of freedom would reduce the contingency margin of the generation installed. Furthermore this knowledge would be particularly relevant for the forthcoming integration of intermittent renewable sources [5]. However, electricity markets are highly complex and the numerous physical constraints of power systems prevent prices from being correlated with environmental emissions.

One way to provide dynamic potential impacts of power consumption would be through life cycle assessment (LCA). Instead of regarding the dynamic emissions factors of the electricity generation, the trades between regions are considered in a dynamic emissions factors of the electricity consumption. The gap among both factors is paramount to understand which are the least damaging periods of electricity use.

The different approaches encompassed in the LCA methodology [6] allow us, first, to assess the impacts of the past use of electricity (attributional approach). Such a perspective provides us information about the environmental issues of DSM during, for example, off-peak hours where an inconvenient and issuing electricity would be traded instead of reduced. Thanks to that, ecological relevancies of various programs of DSM are compared. The second approach, called consequential LCA, is developed in order to identify the marginal emissions associated with a prospective power use [6]. Thus, we assess the response of the power system subject to an increase in use and create a model to predict when the electricity consumption will have the least potential impacts.

Hence, consumers will be aware of the energy sustainability that they decide to use not only through its price but also using an LCA-based indicator. With this DSM program, a smart home would be able to minimize its greenhouse gas emissions or any other of its environmental impacts through a dynamic management of its energy consumption. Moreover, once the model is applied, an LCA of the smart building is conducted to measure its overall impact.

Ultimately, these results could be extended to the case of a smart city in order to measure the decrease of potential environmental impacts the implementation of smart buildings could provide.

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RDF-Based Data Integration for Multi-modal Transport Systems

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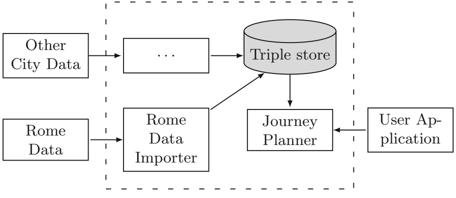
In many cities, the increasing traffic of private and commercial vehicles is straining the transportation infrastructure, and traffic congestion causes significant losses to the economy. In order to provide robust, efficient and accurate multi-modal travel solutions to users, journey planners require accurate, up-to-date, and integrated data. The PETRA EU FP7 project specifically aims at addressing all these issues. Specifically, one of the goals is to create an integrated platform for Smart Cities allowing data producer and consumers to efficiently exchange information. In this demo we will present a platform allowing to import live transportation data from a city using Resource Description Framework (RDF). This platform is part of the PETRA project and the data collected from the city is then retrieved by the Dynamic Optimisation for Intermodal City Transportation (DOCIT) journey planner in order to provide accurate multi-modal routes in Rome and other cities. Our demo proposes the use of RDF to facilitate not only the integration to a journey planner, but also any tasks related to daily activities performed by city operators, for example adding temporary disruptions of bus routes. The use of RDF for storing General Transit Feed Specification (GTFS) and further data provides several advantages when compared to other type of storage: (i) it simplifies querying and managing the data, allowing to easily expose data to users as Linked Data (ii) it provides a transparent model for combining data from the different GTFS CSV files and other data sources (iii) updates can be performed using a standard language instead of using a custom solution. We will also present the evaluation of some of the queries used by the platform, further demonstrating the performances of the system.



The architecture allows us to leverage the traffic data from cities like Rome and Venice (provided as a data dump in GTFS format along with live updates) in the journey planner via a triple-store. By using RDF as an intermediate representation format and a triple-store, the City Data Importer (CDI) can use SPARQL queries to obtain any necessary data and also perform updates over the stored data (e.g., in case of bus delays). As mentioned, the PETRA project builds on DOCIT that is an integrated system providing a multi-modal journey planner under uncertainty.

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DOCIT provides functions such as non-deterministic multi-modal journey plan computation, plan execution monitoring, and re-planning. The demo will consist of live interaction with the system, plus videos of the system in action on sample critical situations.

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