Project acronym:	**PrEstoCloud**
Project full name:	**Proactive Cloud Resources Management at the Edge for efficient Real-Time Big Data Processing**
Grant agreement number:	**732339**

D2.5 PrEstoCloud Semantic Model

Deliverable Editor:	**Yiannis Verginadis (ICCS)**
Other contributors:	**Nikos Papageorgiou, Andreas Tsagkaropoulos, Dimitris Apostolou, Gregoris Mentzas (ICCS)**
Deliverable Reviewers:	**Giannis Ledakis (Ubitech)** **Blaz Novak (JSI)** **Salman Taherizadeh (JSI)**
Deliverable due date:	**6/11/2017**
Submission date:	**06/12/2017**
Distribution level:	**Public**
Version:	**Final**

This document is part of a research project funded by the Horizon 2020 Framework Programme of the European Union

Change Log

Version	Date	Amended by	Changes
0.1	05/09/2017	Yiannis Verginadis (ICCS)	Table of Contents
2.8	28/11/2017	Yiannis Verginadis (ICCS)	Pre-final version ready for internal review
2.9	01/12/2017	Giannis Ledakis (Ubitech)	Internal review comments
2.10	03/12/2017	Blaz Novak (JSI)	Internal review comments
2.11	03/12/2017	Salman Taherizadeh (JSI)	Internal review comments
2.12	05/12/2017	Yiannis Verginadis (ICCS)	Final Version

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List of Abbreviations

The following table presents the acronyms used in the deliverable.

Abbreviation	*Description*
BLOB	Binary Large OBject
CPU	Central Processing Unit
DSL	Domain Specific Languages
eNB	Evolved Node B
GPU	Graphics Processing Unit
HDA	Highly Distributed Applications
MCC	Mobile Cloud Computing
MEC	Mobile Edge Computing
OMG	Object Management Group
OS	Operating System
TOSCA	Topology and Orchestration Specification for Cloud Applications
UAV	Unmanned Areal Vehicle
UML	Unified Modelling Language
VM	Virtual Machine
XMI	XML Metadata Interchange
XML	Extensible Markup Language

Executive Summary

This deliverable reports on the work performed under Task 2.5 with respect to the development of a semantic and extensible model that describes the associations between Big Data processing types, data-intensive application fragmentations (i.e. meaningful separations of code elements for separate deployment), fragments' distribution constraints and potential workload estimations according to the characteristics of Big Data streams (i.e. Velocity, Volume, Variety). Essentially, this model constitutes the background for transparently handling requirements on candidate cloud resources from multiple providers and edge devices with capabilities to host critical parts of Big Data applications. The core of the PrEstoCloud model consists of the Fragmentation Policy model which includes all the application fragmentation aspects for identifying application fragments and guiding their placement over multi-cloud and edge resources. This core part is augmented by two vocabularies: i) the Edge Resources Vocabulary - a structured description of the concepts that can be used for expressing edge resources capabilities - and ii) the Big Data Vocabulary – an imported taxonomy of concepts that can be used to express any relevant Big Data aspects.

Based on the PrEstoCloud model, code annotations will be interpreted and used by the appropriate fragmentation, deployment and reconfiguration recommenders in order to implement the distributed deployment and adaptation of data-intensive applications, on multi-cloud and edge resources. Based on relevant models and ontologies that focus on multi-cloud computing and Big Data aspects modeling, we highlight the additional capabilities offered by the PrEstoCloud model. The model is detailed and serialised, providing fine-grained information on model's core classes, properties and relevant vocabularies developed and exploited. The model serialization in XML Metadata Interchange (XMI), is provided at the end of this document in relevant appendices. Moreover, this document provides an exemplary walkthrough of the model's use and application in a simple scenario, for assisting the reader to better understand the potential use of this artifact.

1. Introduction

1.1 Scope

This work documents a semantic model that will allow Big Data application developers to annotate their code, highlighting meaningful fragmentations of the application functionality, declaring distribution constraints and denoting their potential hosting needs according to workload estimations. These annotations will be interpreted and used by the appropriate recommenders of the Meta-management layer of the PrEstoCloud platform (PrEstoCloud, 2017b) in order to implement the distributed deployment and reconfiguration of data-intensive applications on multi-cloud and edge resources.

In order to transparently handle candidate cloud resources from multiple providers and edge devices with capabilities to host critical parts of Big Data applications, this introduces the need for an appropriate modelling artifact; the PrEstoCloud model. The role of this model includes the following benefits:

- It allows application developers or DevOps to define hosting and reconfiguration requirements in a way that is exploitable by the advanced decision making mechanisms of the PrEstoCloud platform and usable by the control mechanisms that implement the deployment or adaptation decisions.
- It provides a common medium for describing both multi-cloud and edge related hosting requirements.
- It complements the development toolkit of cloud application developers with the capability to guide the partitioning and deployment of application code into fine-grain application fragments (i.e. microservices (Newman, 2015), classes, methods).

The PrEstoCloud model offers these important capabilities that will be exploited by other PrEstoCloud components towards the project's objective of enabling Big Data cloud applications to be deployed and reconfigured on multi-cloud and edge resources.

1.2 Relation to PrEstoCloud Tasks

The introduction of the PrEstoCloud Model as a tool to cover the modelling needs of the PrEstoCloud platform with respect to data-intensive application fragmentation and deployment has been defined in the description of work of the PrEstoCloud project as part of the Task 2.5. A primary input for this work has been the technology review and evaluation provided through the deliverable D2.1 - Scientific and Technological State-of-the-Art Analysis (which reported work from Task 2.1). An additional input is the multi-cloud and edge related requirements that have been aggregated in deliverable D2.2 – Requirements for the PrEstoCloud Platform (which reported work from Task 2.2) in terms of functional and non-functional requirements for transparent cloud application deployment over multi-clouds and edge resources along with runtime adaptation needs. The major relationships between Task 2.5 and other WP2, WP3, WP5 tasks are depicted in Figure 1. Task 2.5 affects and is affected by the architectural decisions that were made as part of Task 2.3. Actually, the PrEstoCloud modelling capabilities affect the way that Meta-management layer components are being designed (Tasks T3.3, T5.1, T5.2, T5.3).

Specifically, the PrEstoCloud model as it is captured in the current deliverable, provides input for the workload predictions, as it describes aspects that should be verified by the appropriate mechanism (Task T5.2). It also constitutes the primary input for the recommenders (Tasks T5.3, T5.4) of the Meta-management layer, which use it to define application fragments or look for appropriate placements and reconfigurations. In addition, this model will constitute the background for designing and implementing the Mobile Context Analyser (Task T3.3) with respect to hosting requirements on edge devices (expressed in model instances) and will affect mobile offload processing aspects (Task 3.4), as it expresses offloadable and onloadable application fragments. Last but not least, this model will guide the situation awareness mechanism operation since the PrEstoCloud model instances will also express, appropriate scalability rules devised by DevOps or application developers.

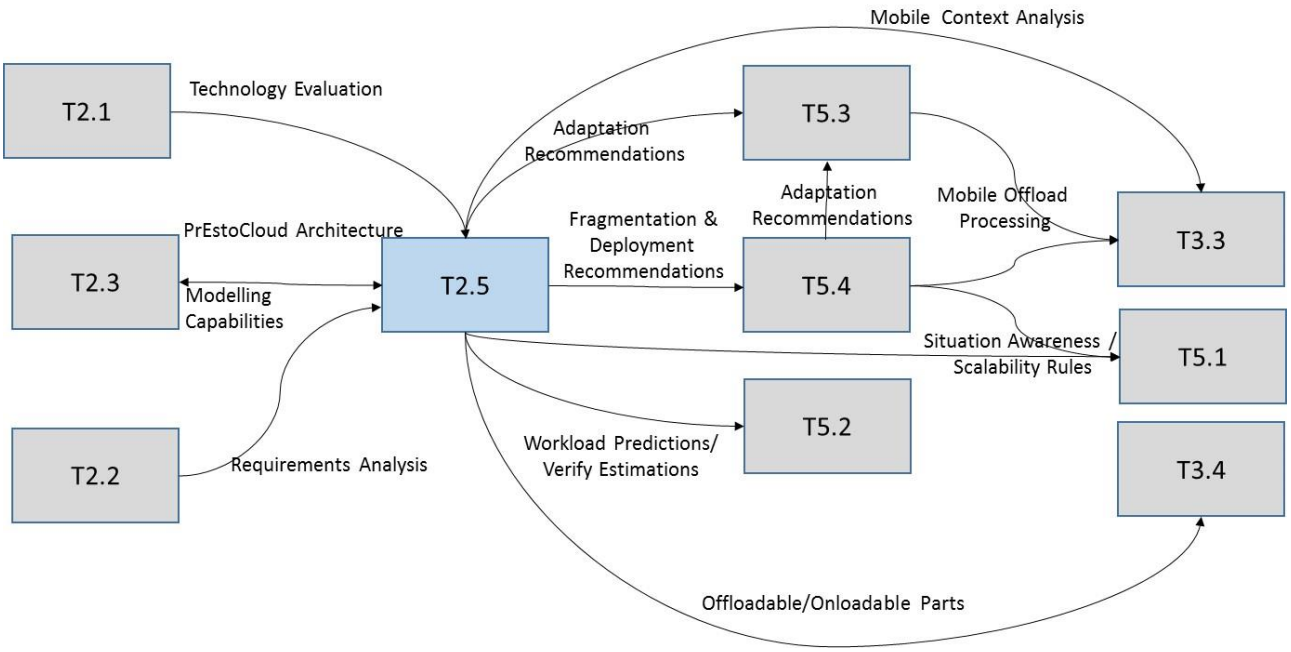

Figure 1: Task 2.5 in PrEstoCloud

1.3 Document Structure

This deliverable starts with an introductory section (Section 1) that presents the main objectives and ideas around the PrEstoCloud model along with its role in the PrEstoCloud platform. Section 2 discusses relevant models and ontologies that focus on multi-cloud computing and Big Data aspects modeling. In Section 3, we detail the main aspects of the PrEstoCloud model, providing in-depth information on model's core classes, properties and relevant vocabularies developed and exploited. In Section 4, we provide an exemplary walkthrough of the model's use and application in a simple scenario, for assisting the reader to better understand the potential use of this artifact. Last, in Section 5, we summarize and provide concluding remarks on the PrEstoCloud model. We note that the serialization of all the aspects of the PrEstoCloud model is provided in the Appendices I and II, while in Appendix III, we accommodate some additional code that complements the illustrative example of Section 4.

2. Relevant Languages, Models & Vocabularies

In this section, we discuss the most interesting and relevant vocabularies, ontologies and languages in the area of multi-cloud computing and Big Data analytics. We detect their core aspects and identify opportunities for re-using concepts that may augment the PrEstoCloud model.

2.1 Big Data Related Models

Based on a thorough state-of-the-art analysis, we came up with several interesting efforts that introduce taxonomies, vocabularies or even more complete ontological models that may even formulate distinct languages. Even the most recent and advanced works focus only on Big Data aspects for multi-cloud deployment, neglecting important capabilities that edge devices might bring.

For example, Ranjan et al. (2015) defined core IaaS and PaaS concepts along with data persistence aspects, addressing cloud resource orchestration programming issues. Höfer and Karagiannis (2011) also identified some of the core cloud application characteristics and provided a tree-structured taxonomy. Their objective was to enable classifications and comparisons among different cloud computing services according to the IaaS/PaaS/SaaS classification. In another approach (Kang & Sim, 2011) the authors presented a search engine for cloud computing systems, introducing the CO-1 and CO-2 ontologies for semantically defining the relationship among cloud services. In order to define the similarity among different cloud services they adopted three types of reasoning, namely: concept similarity reasoning, object property similarity reasoning, and datatype property similarity reasoning. The DICE[1] project is another relevant effort that offers a UML profile and tools that assist software designers to reason about reliability, safety and efficiency of data-intensive applications. The DICE methodology covers quality assessment, architecture enhancement, continuous testing and agile delivery, relying on principles of the emerging DevOps paradigm (Gómez et al., 2016). Moreover, it introduces a Metamodel for describing aspects of big data intensive applications and it was built on top of MARTE (OMG, 2011) and DAM models (Bernardi et al., 2013).

In addition, there is a very relevant effort that refers to the introduction of an extensible Context Model by the ARCADIA[2] project, which aims to provide a novel reconfigurable-by-design Highly Distributed Applications (HDAs) development paradigm over programmable infrastructures. This model is 'multi-faceted' since it consists of complementary models that are conceptually grouped according to their functional purpose and include: a) the ARCADIA Component Model, b) the ARCADIA Service Graph Model, c) ARCADIA Service Deployment Model and d) the ARCADIA Service Runtime Model. All the aspects of the model have been serialized using XML[3] schema notation.

The CAMEL language (Rossini et al., 2015) constitutes another very interesting work that includes a number of concepts by re-using and extending several domain specific languages (DSLs). CAMEL is both a modelling and an execution language that enables the specification of multiple aspects of multi-cloud applications. In CAMEL, a number of concepts have been introduced as hardware, OS, provider or location requirements. The CAMEL language is currently being extended in order to adequately support the data lifecycle management in multi-cloud environments as part of the Melodic[4] project. A significant part of this work involves the introduction of a Metadata Schema that allows the seamless extension of the language. The part that relates to Big Data aspects constitutes a standalone (Big Data) vocabulary that we consider complete enough for re-using it in the PrEstoCloud model. Specifically, although this work does not consider any edge resources aspects in the Big Data vocabulary that it introduces, it is generic enough to provide in a formal

[1] http://www.dice-h2020.eu/

[2] http://www.arcadia-framework.eu

[3] https://www.w3.org/XML/

[4] http://www.melodic.cloud/

way the necessary concepts and properties that will complete the PrEstoCloud model (Section 3). The details of this incorporation are discussed in section 3.4.

2.2 TOSCA Specification

The PrEstoCloud consortium has decided to use and potentially extend or reconfigure the Topology and Orchestration Specification for Cloud Applications (TOSCA), (OASIS, 2013), in order to use a standard specification for describing placement and adaptation requirements for PrEstoCloud-enabled Big Data applications. TOSCA is an OASIS standard which was created to counter the disparity of a standardized view of resources among different cloud providers (OASIS, 2013). The standard uses an XML based language to define the components of an application and their relations using an application topology, and management tasks formulated in management plans. The potential extensions may involve TOSCA constructs that can adequately express requirements with respect to Big Data aspects and edge resources. TOSCA addresses the automation, portability and interoperability aspects of any cloud application which is composed of multiple services. Among others, TOSCA provides the background for automatic deployment, assisting in the fulfillment of the goal of self-deployment and management in cloud applications.

Specifically, each cloud application is encoded as a "Service Template" in TOSCA. The Service Template includes a Topology Template, and the respective management tasks of the application, defined using different management plans (e.g. scale up, scale down and others). Specifically, every Topology Template includes node templates and relationship templates (OASIS, 2013). The node templates are used for the description of the characteristics of a hosting node, while the relationship templates reflect the required relationships between nodes. The templates can be reused, if this is necessary. The management plans are defined as a workflow described using the Business Process Model and Notation (BPMN[5]) or the Business Process Execution Language (BPEL[6]). Using TOSCA constructs a Service Template is properly described and then it can be interpreted by a TOSCA-compliant engine. Based on this interpretation and the necessary interaction with different cloud providers, certain cloud resources can be commissioned or decommissioned in order for a cloud application to be properly deployed.

The TOSCA specification includes numerous fields which describe the properties of the application to be deployed. However, all properties and management plans must be defined by experts, in order to build a model that accurately reflects the needs of the application and the interactions in it. In PrEstoCloud, we aim to complement the existing TOSCA specification by describing in greater depth the Big Data aspects of the data-intensive cloud application, handling the specification of applications that employ Big-Data frameworks (e.g. Apache Storm) and transparently considering multi-cloud and edge resources. Specifically, we aim to create Service Templates which will describe edge and multi-cloud resources in a unified way, while each application component keeps its unique characteristics. The added value of the PrEstoCloud model that we present in this deliverable is that it allows – with the use of code annotations (provided by application developers) for an efficient fragmentation of a Big Data application and permits its deployment on both multi-cloud and edge resources.

[5] http://www.bpmn.org/

[6] https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=wsbpel

3. PrEstoCloud Model

The PrEstoCloud model is introduced as an extensible medium for describing data-intensive application fragmentations, associating them with Big Data processing types and defining fragments' distribution requirements. Moreover, this model allows for associating application fragments with potential workload estimations according to the characteristics of the relevant Big Data streams (e.g. Velocity, Volume, Variety etc.). Based on the description of work (i.e. Task 2.5), the PrEstoCloud platform should allow cloud application developers to annotate their code in order to highlight meaningful fragmentations of the Big Data application functionality and declare distribution constraints and requirements for application fragments placement over multi-cloud and edge resources. The PrEstoCloud model will provide the means for capturing such annotations and serializing them in an appropriate format that constitutes them exploitable by PrEstoCloud components. Specifically, these annotations will be interpreted and used primarily by the Application Fragmentation & Deployment Recommender for performing the initial fragmentation and initial placement recommendation. Moreover, aspects of the information captured through these annotations (e.g. scalability rules) will be used by the Resources Adaptation Recommender for the reconfiguration of data-intensive application fragments as reported in deliverable D2.3.

3.1 Model Overview

The PrEstoCloud model consists of the following parts:

- *Fragmentation Policy model* - it includes all the application fragmentation aspects for identifying application fragments and guiding their placement over multi-cloud and edge resources.
- *Edge Resources Vocabulary* – it corresponds to an initial and extensible structured description of the concepts that can be used for expressing edge resources capabilities (e.g. device location, transmission throughput, battery status, current memory consumption, processing power availability etc.)
- *Big Data Vocabulary* – it includes an extensible taxonomy of concepts that can be used to express any relevant Big Data aspects (e.g. CPU intensiveness of a Big Data processing job, data volume, velocity or variety etc.). We note that this vocabulary is imported and re-used from the Metadata Schema model that was described as part of the Melodic project (Melodic, 2017), as mentioned in Section 2. This is further analyzed in Section 3.4.

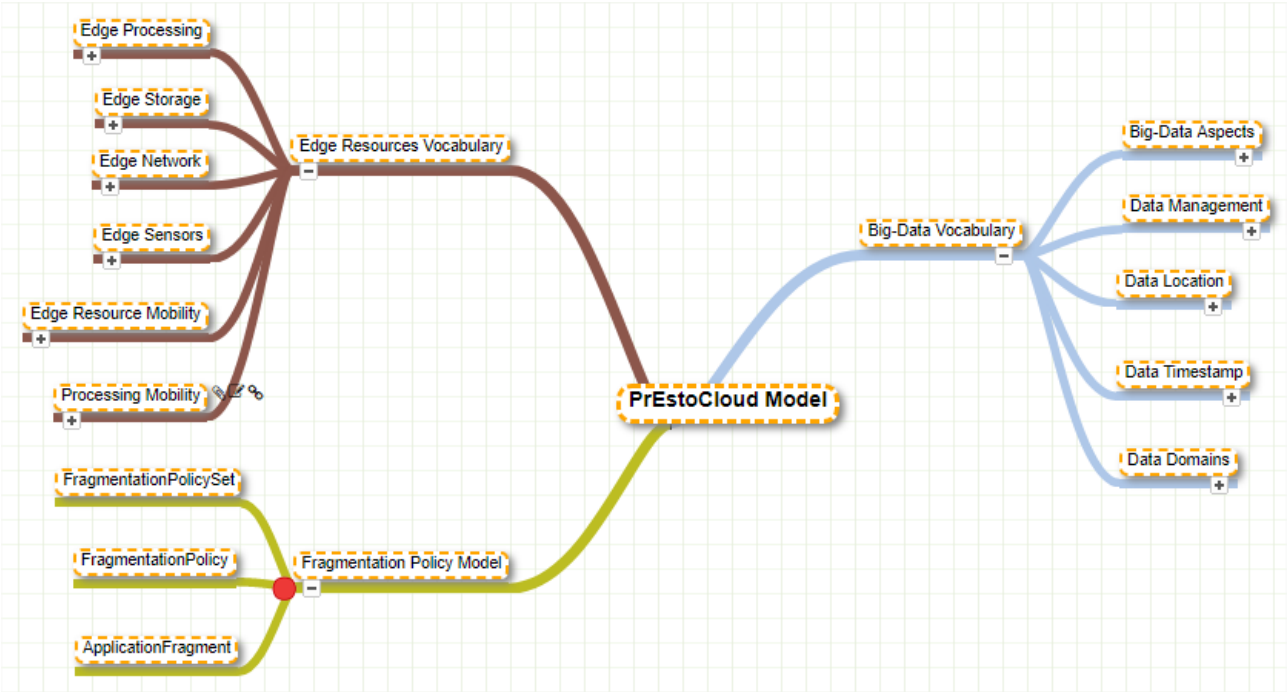

Figure 2: High-level mind map of PrEstoCloud model

Clearly, the core part of the PrEstoCloud model is considered the Fragmentation Policy model that uses the other two vocabularies for expressing requirements and workload estimations. In Figure 2, a high-level mind map is provided as an overview of the PrEstoCloud model. In this mind map the main parts of the PrEstoCloud model are presented along with their first level concepts. Every part of the PrEstoCloud model is analyzed in the following sections 3.2-3.4. We note that the PrEstoCloud model has been serialized in XML Metadata Interchange (XMI[7]) format because it is an adequate and acceptable standard for exchanging metadata information via Extensible Markup Language (XML). Details of the serialization of all the parts of the PrEstoCloud model can be found in the Appendices I-II.

3.2 PrEstoCloud Fragmentation Policy Model

In this section, we present the core part of the PrEstoCloud Model entitled as PrEstoCloud Fragmentation Model. This part of the model includes all the classes and data or object properties needed to describe fragmentation policies for Big Data applications and attach deployment requirements.

3.2.1 PrEstoCloud Fragmentation Policy Model Overview

We present in Figure 3 an overview of the PrEstoCloud Fragmentation Policy Model using a UML class diagram that formally captures the relations between different classes and depicts the classes' attributes as part of the data and object properties definition. We note that in this figure any external to PrEstoCloud model classes have been depicted using the blue color.

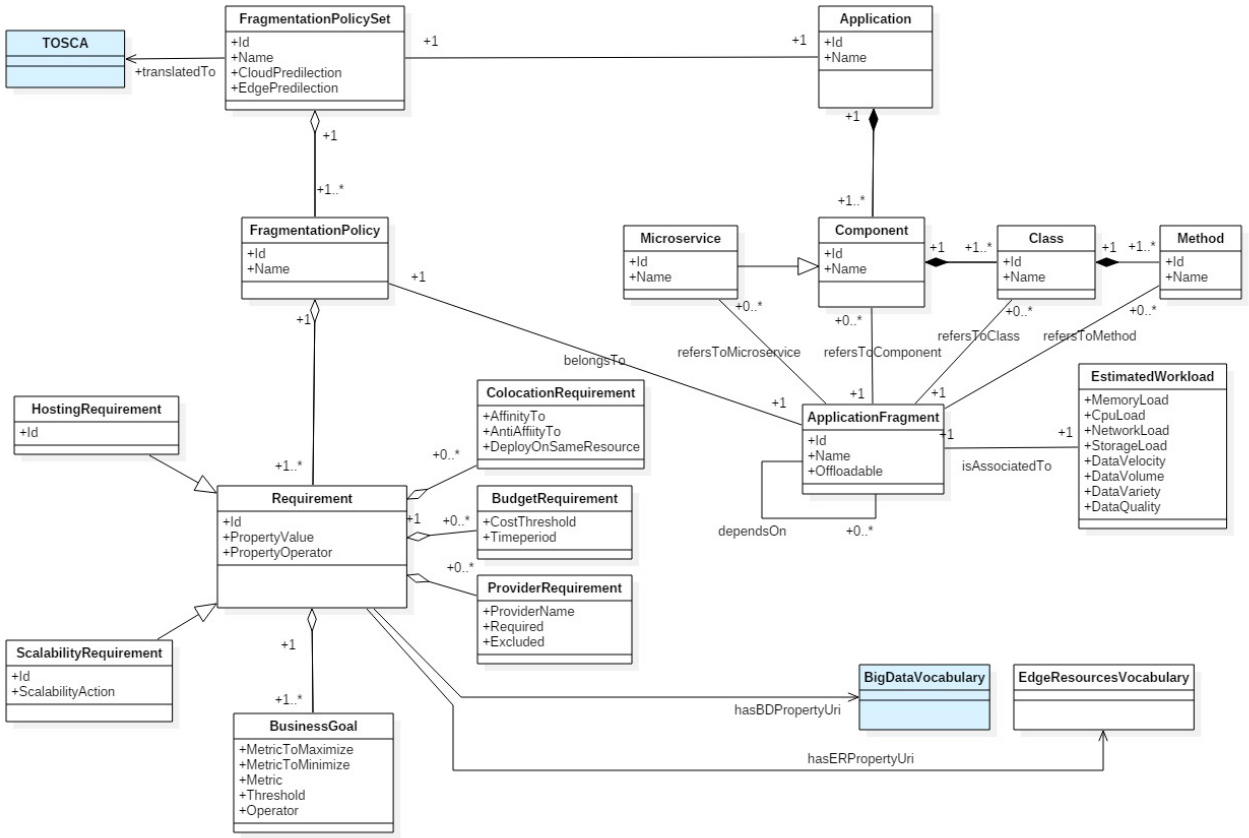

Figure 3: PrEstoCloud Fragmentation Policy Model - UML Class diagram

As shown in Figure 3, the main classes of this model are the *Application Fragment*, *Fragmentation Policy*, *Requirement* and *Fragmentation Policy Set* classes. The associations of these classes can be translated as

[7] http://www.omg.org/spec/XMI/About-XMI/

follows: a *Fragmentation Policy* belongs to exactly one *Application Fragment* for aggregating and expressing *0* to *n* placement *Requirements* for parts of an application functionality that may be deployed on different multi-cloud or edge resources. Such requirements mainly involve *Hosting Requirements* (e.g. Edge resource RAM > 8Gb) and *Scalability Requirements* (e.g. VM CPUUtilization>60% and Edge Network Bandwidth < 5Mbps). These requirements may also aggregate *0* to *n* Budget Requirements (e.g. VMs CostThreshold = 1000 Euros per Timeperiod= 1 month), Colocation Requirements (e.g. it should not be collocated with a certain application component), Provider Requirements (e.g. exclude private Openstack datacenters) and *Business Goals* (e.g. Minimize cost or Response Time < 1ms). Each *Application Fragment* may refer to *0* to *n* application components that may have been structurally (e.g. Microservices or other loosely coupled application building blocks (e.g. Apache Tomcat, MongoDB)) or functionally (i.e. Java Classes composed of Methods) distinguished. One or more *Fragmentation Policies* are aggregated into a *Fragmentation Policy Set* that is attached to an application for expressing some "global" preferences that may bound the subsequent application fragment placement requirements (e.g. Google Cloud and AWS should be only used for applications fragments that should be hosted on cloud resources).

3.2.2 PrEstoCloud Fragmentation Policy Model Details

In this section, we provide the list of all the classes and their data and object properties that appear in the UML class diagram of the PrEstoCloud Fragmentation Policy model (Table 1).

Table 1: PrEstoCloud Fragmentation Policy Model Details

Class	Subclass	*Properties*	Description
Fragmentation Policy Set			This class aggregates and groups all fragmentation policies and as a consequence all their placement requirements respectively of a certain Big Data intensive application's fragments. The use of the Fragmentation Policy Set class allows the DevOps to set preferences that may bound requirement aspects of all its subsequent fragmentation policies.
		Id	This data property refers to a string that can be used as a unique identifier for each defined fragmentation policy set.
		Name	This data property refers to a string that can be used for setting a name for each defined fragmentation policy set.
		Cloud Predilection	This object property associates the Fragmentation Policy Set class with the Provider Requirement Class (not explicitly depicted in Figure 3 with an association arrow in order to avoid cluttering the image) in order to allow DevOps to globally override the cloud provider preference of the individual fragmentation policies (e.g. AWS should be used).
		Edge Predilection	This data property associates the Fragmentation Policy Set class with a string that denotes a property URI from the Edge Resources Vocabulary (not explicitly depicted in Figure 3 with an association arrow in order to avoid cluttering the image) in order to allow DevOps to globally define preferences with respect to the edge devices that will be used in the implementation of individual fragmentation policies (e.g. UAVs or statically located edge resources should be used).
		translatedTo	This object property associates the Fragmentation Policy Set class with the TOSCA class and models the translation of the requirements set per application fragment to an Oasis TOSCA (OASIS, 2013) specification by the appropriate

			PrEstoCloud mechanism (i.e. the Application Fragmentation & Deployment Recommender).
		aggregates Fragmentation Policies	This object property associates the Fragmentation Policy Set class with the Fragmentation Policy class in order to denote the aggregation of one or more policies that indicate how each involved application fragment should be placed over multi-cloud or edge resources.
		isAttachedTo	This object property associates the Fragmentation Policy Set class with the Application class in order to denote that every PrEstoCloud enabled Big Data application can be accompanied by a policy set that groups separate placement requirements for all the application fragments devised by the application developer.
Fragmentation Policy			This class accommodates the aggregation of any kind of placement requirement that should be respected for meaningful application fragments that an application developer devises.
		Id	This data property refers to a string that can be used as a unique identifier for each defined fragmentation policy.
		Name	This data property refers to a string that can be used for setting a name for each defined fragmentation policy.
		aggregates Requirements	This object property has as a range the Requirement class. Based on this a Fragmentation Policy instance aggregates *1* to *n* Requirement class instances.
Application Fragment			This Class is used to denote a part of a Big Data application as a separate fragment that may be scheduled for deployment on multi-cloud or edge resources independently from other parts of a certain application. As an application fragment can be denoted any application component that has already been structurally (e.g. Microservices) distinguished from other parts of the application, or any Class or Method that is functionally distinct from the rest of the Big Data application. We consider only Classes and Methods that are designed to process Big Data originating outside of the application (i.e. incoming data stream).
		Id	This data property refers to a string that can be used as a unique identifier for each defined application fragment.
		Name	This data property refers to a string that can be used for setting a name for each defined application fragment.
		Onloadable	This data property refers to a boolean value that denotes whether or not a certain application fragment can be onloaded on an edge device.
		Offloadable	This data property refers to a boolean value that denotes whether or not a certain application fragment initially designed to be deployed over an edge device can be offloaded to a cloud resource.
		dependsOn	This object property associates an Application Fragment with another application fragment implying that these two fragments should be deployed in proximity. The details on the level of co-location needs (e.g. on the same VM or on

			the same Cloud etc.) is specified through the ColocationRequirement class.
		refersTo Microservice	This object property associates an Application Fragment with a microservice in cases where the application developer or the DevOps wishes to define placement requirements separately for a certain microservice. This microservice constitutes a part of the Big Data application and PrEstoCloud will consider it as a separate application fragment for placement.
		refersTo Component	This object property associates an Application Fragment with an independent application component (e.g. a database). This component constitutes a part of the Big Data application and PrEstoCloud will consider it as a separate application fragment for placement.
		refersToClass	This object property associates an Application Fragment with a component (Java) class (represented as class element in the UML diagram) in cases where the application developer or the DevOps wishes to define placement requirements separately for a certain class. A prerequisite is that this class should process "external" to the application Big Data.
		refersToMethod	This object property associates an Application Fragment with a (Java) method (represented as class element in the UML diagram) in cases where the application developer or the DevOps wishes to define placement requirements separately for a certain method. A prerequisite is that this method should process "external" to the application Big Data.
		isAssociated With	This object property associates an Application Fragment with the Estimated Workload class and allows the application developer or the DevOps to provide workload estimations per application fragment (e.g. expected Data volume). We note such an association may be possible through machine learning techniques.
		belongsTo	This object property associates an Application Fragment with the Fragmentation Policy class in order to allow the application developer or the DevOps to attach a policy to a certain application fragment that will analyse the placement requirements.
Estimated Workload			This class includes the concepts necessary to describe workload estimations from method to component level. Such estimations may be mapped directly to hosting requirements.
		MemoryLoad	This data property associates the Estimated Workload class with a string that expresses linguistically estimations about the memory load that a certain application fragment may cause (e.g. Memory Load = High).
		CpuLoad	This data property associates the Estimated Workload class with a string that expresses linguistically estimations about the CPU load that a certain application fragment may cause (e.g. CPU Load = Medium).
		NetworkLoad	This data property associates the Estimated Workload class with a string that expresses linguistically estimations about

			the network load that a certain application fragment may cause.
		StorageLoad	This data property associates the Estimated Workload class with a string that expresses linguistically estimations about the storage load that a certain application fragment may cause.
		DataVelocity	This data property associates the Estimated Workload class with a string that expresses linguistically estimations about the speed at which data intercepted for processing by a certain application fragment (e.g. Data Velocity = Very High that may correspond to more than 100Gb/s). Based on the PrEstoCloud adopter's need this property may associate the Estimated Workload class with a float value in cases where more concrete (ranges) estimations may be provided by the application developers.
		DataVolume	This data property associates the Estimated Workload class with a string that expresses linguistically estimations about the size of data intercepted for processing by a certain application fragment. As above mentioned the range of this data property may be a float number.
		DataVariety	This data property associates the Estimated Workload class with a string that denotes the different types (e.g. video, audio) of data along with their format (e.g. BLOB, Key-value pairs) that should be processed by a certain application fragment.
		DataQuality	This data property associates the Estimated Workload class with a string that denotes any relevant quality aspects of data to be processed by a certain application fragment (e.g. accuracy, compression or encryption used etc.).
Application			This class of the PrEstoCloud Fragmentation Policy model is used to refer to the Big Data Application that will be deployed on multi-cloud and/or edge resources through the PrEstoCloud platform. With respect to fragmentation we focus on applications that have either been developed following the microservices paradigm or applications where distinct classes and/or methods can be named by the application developer as fragments that independently may process incoming Big Data streams.
		Id	This data property refers to a string that can be used as a unique identifier for an application.
		Name	This data property refers to a string that can be used for setting a name for the application.
		composedOf Components	This object property associates the Application class with Component class in order to denote that every Big Data application is composed of one or more components.
Component			This class refers to the basic constituents of a Big Data application and includes microservices, loosely coupled application building blocks (e.g. Apache Tomcat, MongoDB) and/or software designed to work as a part of a larger application.
		Id	This data property refers to a string that can be used as a unique identifier for each application component.

		Name	This data property refers to a string that can be used for setting a name for each application component.
		composedOf Class	This object property associates the Component class with the Class in order to denote that an application component is the composition of one or more programmatic (Java) classes.
	Microservice		This class refers to a variant of the service oriented architecture (SOA) paradigm that devises an application as a collection of loosely coupled fine-grained services (Newman, 2015). A PrEstoCloud enabled application may be designed as a set of such microservices.
		Id	This data property refers to a string that can be used as a unique identifier for each defined microservice.
		Name	This data property refers to a string that can be used for setting a name for each defined microservice.
Class			The Class is used in order to model a core part of an application component that serves as a template for creating different objects with common properties and behaviours.
		Id	This data property refers to a string that can be used as a unique identifier for each developed class.
		Name	This data property refers to a string that can be used for setting a name for each developed class.
Method			The Method is used in order to model a core part of software component class that describes the desired behaviour of an object.
		Id	This data property refers to a string that can be used as a unique identifier for each developed method of a class.
		Name	This data property refers to a string that can be used for setting a name for each developed method of a class.
Requirement			This Requirement class is used in order to accommodate all the classes and properties that may be used for modelling placement and reconfiguration requirements of a certain Big Data application fragment.
		Id	This data property refers to a string that can be used as a unique identifier for each defined application fragment placement requirement.
		hasBD PropertyUri	This object property associates the Requirement class with the Big Data Vocabulary (external) class. The purpose of this association is to allow for the requirements elicitation with respect to Big Data unique characteristics and the use of concepts that have been formally captured in the specific vocabulary developed as part of the Melodic project.
		hasER PropertyUri	This object property associates the Requirement class with the Edge Resources Vocabulary class. The purpose of this association is to allow for the requirements elicitation with respect to edge devices characteristics and capabilities and the use of concepts that have been formally captured in the specific PrEstoCloud vocabulary.

		PropertyValue	This data property is used to associate a Big Data or Edge related concept (from the respective vocabularies) with a certain value threshold that is required to be respected by the application fragment placement or reconfiguration decision.
		Property Operator	This data property associates the Requirement class with a string that denotes the operator used by the application developer or the DevOps in order to define that certain requirement refers to accomplishing "greater than", "lesser than" or "equal to" the value (of the Property Value) with respect to a BD or ER Property URI.
		aggregates BusinessGoals	This object property associates the Requirement class with the Business Goal class for denoting that a certain requirement is related to the objectives and needs of the organisation (that wants to deploy a Big Data application). Business Goals can be expressed in terms of business metrics that should be minimized, maximised or restricted under or over a certain threshold (e.g. minimize cost, maximize quality).
		aggregates Colocation Requirements	This object property associates the Requirement class with the Colocation Requirement class for grouping several affinity or anti-affinity constraints under the same requirement instance. Such constraints may refer to the need for a certain application fragment to be deployed on the same physical or network location with another application fragment or even with another application.
		aggregates Budget Requirements	This object property associates the Requirement class with the Budget Requirement class for grouping several cost related constraints under the same requirement instance. Such constraints refer to certain cost thresholds per time period that should be respected when a placement or reconfiguration decision is taken.
		aggregates Provider Requirements	This object property associates the Requirement class with the Provider Requirement class for grouping several preferences related to the providers of hosting resources, under the same requirement instance. Such preferences may refer to certain providers that should or should not be used for an application fragment.
	Hosting Requirement		This is a subclass of the Requirement class and is used to refer to hardware level resources capabilities needed to properly host a certain application requirement (e.g. number of VCPUs, RAM etc.)
		Id	This data property refers to a string that can be used as a unique identifier for each defined application fragment hosting requirement.
	Scalability Requirement		This is a subclass of the Requirement class and it is used to refer to details on how and when certain reconfigurations with respect to hosting multi-cloud and edge resources should be made according to some rules.
		Id	This data property refers to a string that can be used as a unique identifier for each defined application fragment scalability requirement.

		ScalabilityAction	This data property associates the Scalability Requirement class with a string that denotes the kind of action that should be followed once a scalability rule is triggered (e.g. scale out by adding 2 VMs and 1 edge device).
Business Goal			This class denotes certain business level requirements according to the objectives and needs of the organisation (that wants to deploy a Big Data application).
		MetricTo Maximize	This data property associates the Business Goal class with a string that expresses a certain business metric that should be maximised (e.g. quality of experience) for satisfying certain business goals with respect to a Big Data application.
		MetricTo Minimize	This data property associates the Business Goal class with a string that expresses a certain business metric that should be minimized (e.g. cost) for satisfying certain business goals with respect to a Big Data application.
		Metric	This data property associates the Business Goal class with a string that expresses a certain business metric that should be restricted under or over a certain threshold for satisfying certain business goals with respect to a Big Data application.
		Threshold	This data property associates the Business Goal class with a numeric value that expresses a certain business metric's desired value.
		Operator	This data property associates the Business Goal class with a string that expresses whether a certain metric should be equal, greater or lesser than a threshold for satisfying certain business goals with respect to a Big Data application.
Provider Requirement			This class is used for modelling preferences related to the providers of hosting multi-cloud or edge resources. Such preferences refer to certain providers that should or should not be used for an application fragment.
		ProviderName	This data property associates the Provider Requirement class with a string that refers to the provider name that offers resources that may be used to host a certain application fragment.
		Required	This data property associates the Provider Requirement class with a boolean value that denotes whether or not a certain provider should definitely be used to host an application fragment.
		Excluded	This data property associates the Provider Requirement class with a boolean value that denotes whether or not a certain provider should not be used to host an application fragment.
Budget Requirement			This class is used to model cost related constraints that should be respected when making decisions on placement and reconfigurations application fragments.
		CostThreshold	This data property associates the Budget requirement with a float value that refers to the desired upper limit for paying per hosting resource use.

		TimePeriod	This data property associates the Budget requirement with a string that restricts the period of time set for a certain cost threshold with respect to cloud resources use.
Colocation Requirement			This class refers to physical or network location placement constraints with respect to other applications or application fragments.
		AffinityTo	This object property associates the Colocation Requirement class with the Application class to denote the need to place a certain application fragment under the same (e.g. same VM) or the closest possible hosting resource (e.g. same Cloud) that is used for another application or application fragment (not explicitly depicted in Figure 3 with an association arrow in order to avoid cluttering the image).
		AntiAffinityTo	This object property associates the Colocation Requirement class with the Application class to denote the need to avoid placing a certain application fragment under the same hosting resource that is used for another application or application fragment (not explicitly depicted in Figure 3 with an association arrow in order to avoid cluttering the image).
		DeployOnSame Resource	This data property associates the Colocation Requirement class with a boolean value that denotes whether or not there is the need of using the exact same resource (cloud or edge) for deploying a certain application fragment. We note that this will be set by default true in cases there has been expressed a direct dependency between two different fragments (through the use of the dependsOn object property of the ApplicationFragment Class).
Edge Resources Vocabulary			This class refers to a PrEstoCloud vocabulary that includes all the classes and properties to be used for describing Edge resources that can take part in the distributed deployment of big data applications. This class is further analysed in section 3.3.
Big Data Vocabulary			This external class (developed in Melodic project) refers to a vocabulary that includes all the classes and properties to be used for describing Big Data characteristics that should be considered for making Big Data application placement decisions. This class is further analysed in section 3.4.
TOSCA			This external class refers to the Oasis TOSCA (OASIS, 2013) that will be used to translate the application fragments placement decisions to a standard specification that can be propagated to the PrEstoCloud control layer for implementation.

3.3 Edge Resources Vocabulary

In this section, we present a vocabulary that was developed in PrEstoCloud (as part of the PrEstoCloud model) for describing edge resources. This vocabulary has been designed by structuring all the relevant concepts in a taxonomy that encompass all the classes and properties that can be used for describing Edge resources to take part in the distributed deployment of big data applications.

3.3.1 Edge Resources Vocabulary Overview

We provide a class/subclass diagram (Figure 4) that provides a bird's eye view of the certain vocabulary that carries the necessary core concepts for describing application fragments requirements through the PrEstoCloud Fragmentation Policy model.

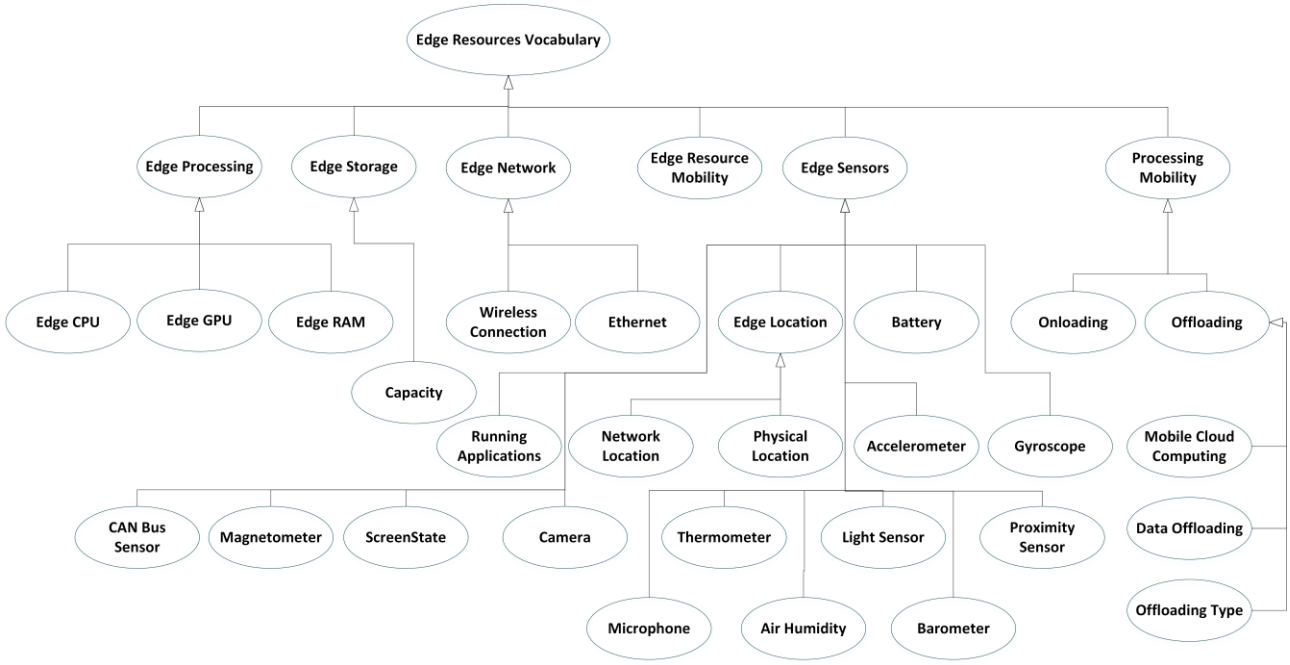

Figure 4: PrEstoCloud Edge Resources Vocabulary – Class/Subclass Diagram

3.3.2 Edge Resources Vocabulary Details

In Table 2, we discuss all the classes with their subclasses along with their data and object properties that belong to the Edge Resources vocabulary. We note that the ranges of the data properties that are mentioned in the following table refer to primitive or derived datatypes of the W3C XML Schema[8]. For example a data property with a range double refers to the *xsd:double*[9]; meaning a value space of double (64 bits) floating-point numbers as defined by the Institute of Electrical and Electronic Engineers (IEEE, 1985). As mentioned in Section 3.2.1, this vocabulary will augment the certain attributes of the PrEstoCloud Fragmentation Policy Model. We expect that based on the PrEstoCloud adopters' needs that this vocabulary can be extended and/or refined.

[8] https://www.w3.org/XML/Schema

[9] https://www.w3.org/TR/xmlschema-2/#double

Table 2: Edge Resources Vocabulary Details

Class Taxonomy Levels			*Properties*	Description
Edge Processing				This class involves all the concepts that can be used for describing edge device features relevant to their processing capability.
			hasDeviceModel	This data property associates the Edge Processing class with a string that denotes the name of the hardware model of a certain edge device.
			isDataSource	This data property associates the Edge Processing class with a boolean value that denotes whether or not a certain edge device is producing data streams to be processed by a big-data intensive application.
			hasManufacturer	This data property associates the Edge Processing class with a string that denotes the name of the producer of a certain edge device.
			hasTransmission Power	This data property associates the Edge Processing class with a positive integer that denotes the power output level of an edge device (usually measured in dB). The used transmission power has always an effect on the battery consumption of an edge device.
			hasElapsedTime SinceLastRestart	This data property associates the Edge Processing class with a (xsd:) duration value that denotes the duration of continuous operation of an edge device.
			hasCauseOfRestart	This data property associates the Edge Processing class with a string that denotes the reason of the latest restart of an edge device.
			hasIdleTime	This data property associates the Edge Processing class with a (xsd:) duration value that denotes the total time during which a certain edge device was not processing or transmitting data.
			hasOS	This data property associates the Edge Processing class with a string that denotes the operating system that a certain edge device has installed.
			hasUptime	This data property associates the Edge Processing class with a (xsd:) duration value that denotes the total time during which a certain edge device was accessible through a certain network connection.
	Edge CPU			This class refers to Edge resources that use and may offer Central Processing Units (CPUs) for executing software instructions in the form of arithmetic, logical, control and input/output operations.
			hasCPUUtilization	This data property associates the Edge CPU class with a double that expresses the usage percentage for a certain processing unit at a certain point in time.
			hasMIPs	This data property associates the Edge CPU class with a positive integer that refers to the

				processing speed of a certain edge device, measured in million instructions per second.
			hasMFLOPs	This data property associates the Edge CPU class with a positive integer that expresses the processing capacity for performing mega floating-point operations per second.
			hasMinNumberof Cores	This is a data property of the Edge CPU class with a range that is a positive integer referring to the minimum number of CPU cores required by an edge device.
			hasMaxNumberof Cores	This is a data property of the Edge CPU class with a range that is a positive integer referring to the maximum number of CPU cores required by an edge device.
			hasNumberofCores	This is a data property of the Edge CPU class with a range that is a positive integer referring to the actual number of CPU cores available on an edge device.
			hasFrequency	This is a data property of the Edge CPU class that captures in a positive integer the CPU performance by specifying the frequency of CPU operation, defined in cycles per second.
	Edge GPU			This class refers to the details of Edge devices equipped with graphics processing units (GPUs), i.e. specialised electronic circuits typically used to render images and videos that can be repurposed to help solve computationally intensive mathematical problems.
			hasClockSpeed	This data property has as range a positive integer and captures the operating speed of a GPU, expressed in cycles per second.
			hasMinNumberof Cores	This data property refers to a positive integer that expresses the minimum number of GPU cores required from an Edge device for placing a certain Big Data intensive processing job.
			hasMaxNumberof Cores	This data property refers to a positive integer that expresses the maximum number of GPU cores required from an Edge device for placing a certain Big Data intensive processing job.
			hasNumberofCores	This data property refers to a positive integer that expresses the actual number of GPU cores available on an Edge device.
			hasStartUsageDate	This data property associates the Edge GPU class with the (xsd:) dateTime that denotes the time that a certain GPU began to operate. It indirectly reveals the age of the graphics processing unit of a certain edge device.
			hasManufacturer	This data property associates the Edge GPU class with a string that denoted the manufacturer of a certain graphics processing unit.
			hasGPUUtilization	This data property associates the Edge GPU class with a double that expresses the usage

				percentage for a certain graphics processing unit at a certain point in time.
			hasMFLOPs	This data property associates the Edge GPU class with a positive integer that expresses the processing capacity of GPU for performing mega floating-point operations per second.
			hasPEperCUs	This data property associates the Edge GPU class with a positive integer that refers to the number of processing elements per compute unit that a certain GPU of an edge device offers.
			hasWarpSize	This data property associates the Edge GPU class with a positive integer that expresses the number of threads in a warp which is a sub-division used to coalesce memory accesses and instruction dispatches.
			hasMaxConcurrent Workgroups	This data property associates the Edge GPU class with a positive integer that expresses the maximum number of workgroups simultaneously executed on compute units.
	Edge RAM			This class corresponds to the memory capabilities of an edge device.
			hasMinRAM	This data property associates the Edge RAM class with a positive integer that represents the least amount of memory capacity required out of an edge device.
			hasMaxRAM	This data property associates the Edge RAM class with a positive integer that represents the largest amount of memory capacity required out of an edge device.
			hasFreeMemory	This data property associates the Edge RAM class with a double that denotes the amount of unused memory currently available in an edge device.
			hasUsedMemory	This data property associates the Edge RAM class with a double that denotes the amount of used memory in an edge device.
			hasRAM	This data property associates the Edge RAM class with a positive integer that represents the actual amount of memory capacity that is available in edge device.
Edge Storage				This class describes the storing capabilities that are required or offered by a certain edge device.
			hasStorageUsage	This data property associates the Edge Storage class with a double that expresses the percentage of storing capacity used for persisting data on an edge device.
			hasWrite Throughput	This data property associates the Edge Storage class with a float that expresses the speed in which data can be stored in an edge device.

			hasRead Throughput	This data property associates the Edge Storage class with a float that expresses the speed in which data can be retrieved from an edge device.
	Capacity			This subclass includes details relevant to the size of storage capacity requested or offered by an edge device.
			hasMinDisk	This data property associates the Capacity class with a positive integer that expresses the minimum storage size required on an edge device to onload a certain processing job (application fragment).
			hasMaxDisk	This data property associates the Capacity class with a positive integer that expresses the maximum storage size required on an edge device to onload a certain processing job (application fragment).
			hasDisk	This data property associates the Capacity class with a positive integer that expresses the actual storage size available on an edge device.
Edge Network				This class refers to the details of the network connectivity of an edge device that may offload or onload processing jobs (application fragments).
			hasBandwidth	This data property associates the Edge Network class with a float value that expresses the number of bits that can be relayed per unit of time between an edge device and a cloud resource once a certain network is used.
			hasLatestCarrier Transitions	This data property associates the Edge Network class with a string that denotes the previous changes in telecom carriers used for transmitting and receiving data.
			hasUploadSpeed	This data property associates the Edge Network class with a float value that expresses the number of bits that can be uploaded per unit of time (usually seconds) from an edge device to a cloud resource through a certain network.
			hasDownloadSpeed	This data property associates the Edge Network class with a float value that expresses the number of bits that can be downloaded per unit of time (usually seconds) from a cloud resource to an edge device through a certain network.
			hasConnection Quality	This data property associates the Edge Network class with an integer that expresses the number of data packets lost out of all the packets transmitted (in a percentage) between an edge device and a cloud. The lower is this percentage the higher the connection quality is considered.
			hasJitter	This data property associates the Edge Network class with an integer that expresses in seconds any deviation from true periodicity of a presumably periodic signal, often in relation to a reference clock signal (Wolaver, 1991).

	Wireless Connection			This subclass accommodates all the details that characterize the network through which an edge device is connected to the cloud, using data connections over the air between network nodes (Miao et al., 2016). Instances of this class can be e.g. 3G, 4G, 5G or Wifi.
			usesBackhaul Technology	This data property associates the Wireless Connection class with a string that expresses the technology used for implementing intermediate links between the backbone network and the small subnetworks at the edge of the entire hierarchical telecommunications network used (Muntean, 2012) (e.g. fiber, microwave, LTE).
			usesBackhaul Topology	This data property associates the Wireless Connection class with a string that expresses the structure used for the backhaul portion of the network that connects edge devices with the cloud (e.g. ring, tree, full mesh). The combination of the appropriate technology with the right topology may have significant benefits for the quality of the network connection (e.g. full mesh topology combined with fiber or microwave connection reduces the execution latency (Mach & Becvar, 2017)).
			hasTransmission Security	This data property associates the Wireless Connection class with a string that denotes the communications security used for protecting transmissions from interception and exploitation by unauthorized third parties (e.g. frequency hopping, cryptographic algorithm etc.) (Lichtman et al., 2016).
			hasTelcoProvider	This data property associates the Wireless Connection class with a string that denotes the name of the telecommunications company that undertakes the network connection between edge devices and cloud.
			hasCellSignal Strength	This data property associates the Wireless Connection class with an integer that expresses the cell reception signal measured in dBm (i.e. the power ratio in decibels (dB) of the measured power referenced to one milliwatt (mW)).
			hasWiFifSignal Strength	This data property associates the Wireless Connection class with an integer that expresses the WiFi reception signal measured in dBm (i.e. the power ratio in decibels (dB) of the measured power referenced to one milliwatt (mW)).
	Ethernet			This subclass includes all the Edge network details that refer to the connectivity of edge devices using cable as a shared medium in conjunction with hubs or switches.
Edge Sensors				This class accumulates all the details of software or hardware equipment available to edge devices for aggregating and providing data that characterize the state of the device.

			hasDeviceUniqueID	This data property associates the Edge Sensors class with an integer that uniquely identifies every edge device connected to the PrEstoCloud platform.
			hasBluetoothStatus	This data property associates the Edge Sensors class with a string that denotes the Bluetooth connection status of an edge device (e.g. Off, Connected, Undetermined).
			hasWiFiStatus	This data property associates the Edge Sensors class with a string that denotes the WiFi connection status of an edge device (e.g. Off, Connected, Undetermined).
	Edge Location			This subclass includes any location related information that allows to pinpoint an edge device at any given time.
		Network Location		This subclass include information that describes the network point under which an edge device is accessible.
			hasIP	This data property associates the Network Location class to a string value that represents the public IP of an edge device.
		Physical Location		This subclass encapsulates all the concepts that can be used for describing the current physical location of an edge device.
			hasLat	This object property associates the Physical Location with the geographical latitude of an edge location in degree/minute/second (DMS) format. The range of this property is the class: http://schema.org/latitude
			hasLong	This object property associates the Physical Location with the geographical longitude of an edge location in degree/minute/second (DMS) format. The range of this property is the class: http://schema.org/longitude
			hasElevation	This object property associates the Physical Location with the geographical elevation of an edge location (especially valuable information for edge devices like UAVs). The range of this property is the class: http://schema.org/elevation
			hasSpeed	This data property associates the Physical location with a float value that denotes how fast a certain edge device changes its current location.
			has Accuracy	This data property associates the Physical location with a float value that denotes how meticulous the edge device location sensor is.
	Battery			This class involves all the information related to the battery and power consumption of a certain edge device.
			hasPowerLevel	This data property associates the Battery class with an integer that denotes as a percentage the remaining battery life of a certain edge device. If

				the certain device is constantly plugged into the power grid then this value will be always 100%.
			hasLatestCharging	This object property associates the Battery class with a point in time in the form hh:mm:ss that expresses when was the last time that a certain edge device was fully charged. The range of this property is: http://schema.org/dateTime
			hasLatestCharging Duration	This data property associates the Battery class with a (xsd:) duration value that denotes for how long the certain edge device was or is being charged.
	Accelero-meter			This subclass refers to an edge device sensor and its data that constitute measurements on the rate of velocity change of a device (Tinder, 2007).
	Gyroscope			This subclass refers to an edge device sensor that it is used for measuring the device's (e.g. UAV) orientation and angular velocity (Tao et al., 2012).
	Magnetome ter			This subclass refers to an edge device sensor that measures the direction, strength, or relative change of Earth's magnetic field along three perpendicular axes X, Y and Z, at a particular location. In PrEstoCloud this can involve valuable information about the precise location and direction of device movement.
	Proximity Sensor			This subclass refers to an edge device sensor that is able to detect the presence of nearby objects (e.g. by measuring changes in an electromagnetic field).
	Light Sensor			This subclass refers to an edge device sensor able to detect the current ambient light level around a certain device (i.e. how bright/dark it is). This information may be valuable in domain specific PrEstoCloud scenarios (e.g. based on the current level of ambient light, the system can expect variations in the volume of a video stream coming from an edge device).
	Barometer			This subclass refers to an edge device sensor able to measure the atmospheric pressure in the area where the edge device is located, for forecasting short term changes in the weather (Muralidharan, 2014). This information may be valuable in domain specific PrEstoCloud scenarios (e.g. the deterioration of the wireless connectivity of UAV due to bad weather).
	Thermo-meter			This subclass refers to an edge device sensor able to measure the device's internal and external temperatures. Such information might give additional insights with respect to power consumption variations.
	Air Humidity			This subclass refers to an edge device sensor able to measure the amount of water vapor in the air. This information may be valuable in domain

				specific PrEstoCloud scenarios where network connectivity issues might be expected.
	Camera			This subclass refers to the capability of an edge device to capture and transmit images and/or video through a certain network.
			hasResolution	This data property associates the Camera class with a float value that expresses the image quality usually measured in megapixels.
			hasZoom	This data property associates the Camera class with an integer that denotes the zooming capabilities of a camera installed on an edge device
			hasSpectralRange	This data property associates the Camera class with a string that denotes the visible spectrum for the camera installed on an edge device (e.g. 0.8 - 1.7 microns).
			hasStabilisation	This data property associates the Camera class with a boolean value that denotes whether or not there is hardware or software image stabilizing capabilities for a certain edge device.
			hasDistortionErrors	This data property associates the Camera class with a boolean value that denotes whether or not there are any optical or perspective errors detected in the output of the camera. This might be valuable information for domain specific scenarios.
	Microphone			This subclass refers to the capability of an edge device to capture and transmit sound through a certain network.
	CAN Bus Sensor			This subclass refers to the capability of an edge device to receive CAN[10] bus messages from attached sensors.
			hasMessageID	This data property associates the CAN Bus Sensor class with a positive integer that denotes the ID of messages received from the sensor bus.
	Running Applications			This subclass refers to the capability provided by dedicated software to capture and transmit information about the list of applications that are currently running on an edge device. In case where the edge device is a mobile phone then this "sensor" may also provide more fine-grained information about applications running in the foreground versus applications running in the background.
	Screen state			This subclass brings details about edge devices that have a screen (e.g. mobile phones) and basically involve information about when and for

[10] Controller Area Network – a network type commonly used in vehicles

				how long the screen is on. This is important information with respect to the battery consumption.
Edge Resource Mobility				This class captures the information related to how often and how fast a certain edge device may change its location (e.g. None, Low, Medium, High).
Processing Mobility				This class involves all the relevant concepts that describe important aspects for the offloading and onloading of processing jobs *from* or *to* edge devices respectively. In PrEstoCloud the processing jobs will be *sent to* or *acquired from* multi-cloud resources, respectively.
			hasExecution Latency	This data property associates the Processing Mobility class with a float value that denotes the time delay introduced in a processing job due to its distance from the data source (i.e. the closest to the data source the processing takes place, the lower the latency will be).
			hasExecutionTime	This data property associates the Processing Mobility class with a (xsd:) duration value that denotes the time needed for completing a certain processing job either on the edge device or on cloud resource. In case of continuous jobs (e.g. Storm jobs) this property may express the time needed for processing a certain amount of incoming data streams.
			hasTransmission Delay	This data property associates the Processing Mobility class with a float value that denotes the time delay introduced to the processing execution time because of the transmission and reception of the offloaded or onloaded code and data (Mach & Becvar, 2017).
			hasMECServer	This data property associates the Processing Mobility class with a string that identifies the Mobile Edge Computing (MEC) server, responsible for allocation, management and release of the virtualized computation resources (ETSI, 2016).
			hasEdgeEnergy Consumption	This data property associates the Processing Mobility class with a float value that denotes the energy consumption of a processing job implemented on a certain edge device.
	Onloading			This subclass includes concepts for describing aspects of the onloading of processing jobs to an edge device from multi-cloud resources (e.g. one or more MEC servers). Basically, this corresponds to application fragments with processing jobs that are more appropriate to be handled on the edge devices because of their proximity to the data sources.
			hasStream TransformationJob	This data property associates the Onloading class with a string value that denotes the unique resource identifier of a processing job that can be onloaded to the edge device for performing

				certain transformations over the outgoing (from the edge device) data streams (e.g. UAV that transmits video to the cloud resources – may be onloaded with a processing job that transcodes the video stream before transmitting it).
			isDataSource	This data property associates the Onloading class with a boolean value that reveals whether or not a certain edge device that might be considered for processing allocation, acts also as a data source (i.e. provides data streams to the multi-cloud resources).
			hasEdgeEnergy OnloadingMobility	This data property associates the Processing Mobility class with a float value that expresses the amount of energy consumed for receiving onloaded code (and data, if applicable) from the MEC.
	Offloading			This subclass includes concepts for describing aspects of the offloading of processing jobs from an edge device to multi-cloud resources. A prerequisite is that a certain application can be divided into offloadable and non-offloadable parts.
			hasOffloadable Parts	This data property associates the Offloading class with a string value that denotes the unique resource identifier of an application fragment that can be offloaded from the edge device to the cloud resource(s).
			hasNonOffloadable Parts	This data property associates the Offloading class with a string value that denotes the unique resource identifier of an application fragment that cannot be offloaded from the edge device to the cloud resource(s).
			hasEdgeEnergy OffloadingMobility	This data property associates the Processing Mobility class with a float value that expresses the amount of energy consumed for: i) transmitting offloaded code and data for computation to the MEC and ii) receiving results of the computation from the MEC (Mach & Becvar, 2017).
		Mobile Cloud Computing		This subclass involves aspects of the mobile cloud computing (MCC) concept, where a user equipment (e.g. mobile phone) may exploit computing and storage resources of powerful centralized clouds, which are accessible through a core network of a mobile operator and the Internet (Hoang et al., 2013).
			usesDistantCloud Resource	This data property associates the Mobile Cloud Computing class with a string value that denotes the unique resource identifier of cloud resource(s) that are distant to the edge device.
			usesCloudResources inProximity	This data property associates the Mobile Cloud Computing class with a string value that denotes the unique resource identifier of cloud resource(s)

				that are close to the edge device (i.e. minimum lag for accessing them).
		Mobile Edge Computing		This subclass involves aspects of the mobile edge computing (MEC) concept, where the computation and storage resources are brought closer to the edge of a mobile network in order to enable the placement of processing jobs on the edge devices (i.e. onloading) while meeting strict delay requirements (Mach & Becvar, 2017).
			hasEdgeDevice InProximity	This data property associates the Mobile Edge Computing class with a string value that denotes the unique resource identifier of close by edge devices.
			hasWiFiConnection	This data property associates the Mobile Edge Computing class with a boolean value that expresses the use of a WiFi connection in order for the edge device to transmit and receive data.
			hasOffset	This data property associates the Mobile Edge Computing class with a positive integer that represents the number of hops between the Evolved Node B (eNB) to which a user equipment (e.g. mobile phone) is connected and the location of the MEC server where the processing job has been offloaded (Mach & Becvar, 2017).
		Data Offloading		This subclass refers to the details on data that should be offloaded along with the processing job to multi-cloud resources.
			hasDataSource	This data property associates the Data Offloading class with a string that denotes the origin of the data to be offloaded (usually the identifier of the edge device).
			hasDataOffloading Target	This data property associates the Data Offloading class with a string that denotes the target cloud resource where the data should be offloaded.
		Offloading Type		This subclass refers to aspects of offloading types which may include the local execution or the complete or partial offloading of processing jobs from an edge device to one or more cloud resources.
			hasLocalExecution	This data property associates the Offloading Type class with a boolean value that denotes whether or not all processing jobs of a certain application will be executed locally on a certain edge device.
			hasFullOffloading	This data property associates the Offloading Type class with a boolean value that denotes whether or not all processing jobs of a certain application will be moved for execution on one or more cloud resources.
			hasPartial Offloading	This data property associates the Offloading Type class with a boolean value that denotes whether or not a fraction of the processing jobs of a certain

				application will be moved for execution on one or more cloud resources.

3.4 Big-Data Vocabulary

As already mentioned, the PrEstoCloud project will try to re-use and exploit open source tools and techniques that already exist in order to realise its visionary goals. This is the case with the specific part of the PrEstoCloud model that involves a vocabulary for Big-Data. We will re-use the model already provided by the Melodic project (Melodic, 2017) that progresses in parallel to PrEstoCloud but focuses on multi-cloud deployment of data-intensive applications with a special emphasis on the management of the Big-Data lifecycle. Although, the Melodic work doesn't consider edge devices at all, we find the part of the Melodic Metadata Schema as valuable and reusable since it includes all the classes and properties that can be used in order to describe Big data aspects (e.g. Volume, Velocity, acquisition, processing type, data domains). Essentially, such aspects may characterize the expected, predicted or current load of big data applications. This information may guide the way that big data application fragmentation will be implemented. Specifically, Figure 5 provides an overview of the Big Data Model depicting the details of its top level concepts in a two-level hierarchical tree. A detailed overview of this model and its part (Big-Data Model) that we are reusing in PrEstoCloud can be found here: http://melodic.cloud/assets/images/MELODIC_Model_vFinal.png. For completeness reasons, in this section we describe only the top level concepts in order to make obvious to the user, the way that this vocabulary can be successfully reused for PrEstoCloud's purposes without repeating all the details that have already been available (Melodic, 2017). Moreover, the latest serialised version of this vocabulary can be found here: https://bitbucket.7bulls.eu/projects/MEL/repos/metadata-schema/browse/.

3.4.1 Big-Data Model Overview

Figure 5 involves a class/subclass diagram that provides a bird's eye view of the certain sub-model that we are reusing as Big-Data related vocabulary.

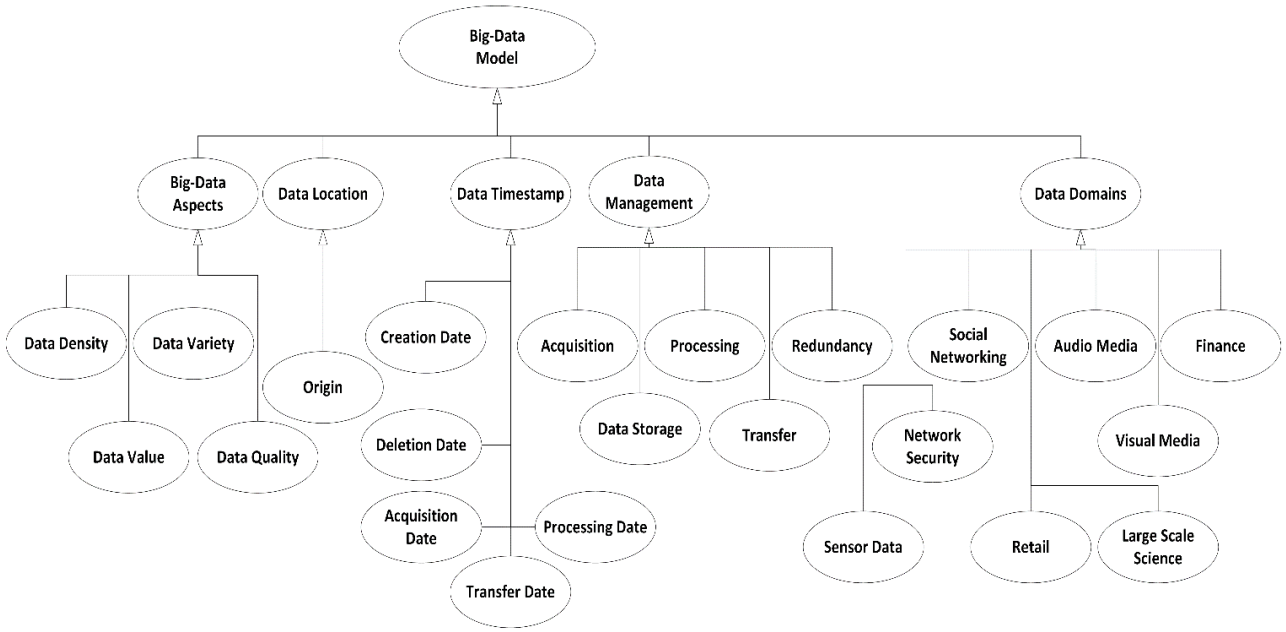

Figure 5: Big-Data Model – Class/Subclass Diagram

3.4.2 Big-Data Model Details

The Big Data Model refers to the following top-level concepts:

- Big Data Aspects
- Data Location
- Data Timestamp

- Data Management
- Data Domains

For each of these top-level core classes, we provide a brief description while we mention their respective subclasses in Table 3. The classes, subclasses and properties existing in this sub-model will be used as concepts for defining Big-Data related requirements of fragmentation policies and also for listing workload estimations at application, component, microservice, and class or method level.

Table 3: Big-Data Model Top-Level Details

Main Taxonomy Classes	Description
Big Data Aspects	This class encapsulates all the attributes that can be used as a vocabulary in order to describe the main characteristics of big data to be processed by big data intensive applications hosted on multi-clouds. It involves several subclasses and properties like Data Density, Data Variety, Data Quality and Data Value.
Data Location	This class encapsulates all the concepts that can be used for describing the origin of data or the current or required physical/ network location where the data can be stored or processed by a big data intensive application. It involves among others subclasses like Batch Origin and Stream Origin.
Data Timestamp	This class includes all the necessary concepts for describing the temporal characteristics of data artifacts to be processed by a big data intensive application. It involves among others subclasses like Creation Date, Deletion Date, Acquisition Date, Processing Date and Transfer Date.
Data Management	This class encapsulates all the relevant concepts that can be used in order to describe major technological choices with respect to how big data is acquired, stored, processed, transferred or replicated for redundancy reasons. It involves among others subclasses like Acquisition, Data Storage, Processing, Transfer, and Redundancy. All these classes have their own subclasses for providing a fine-grained vocabulary. For example the Processing class encapsulates all the concepts that can be used for describing and classifying the various types of big data processing that can be conducted by big data intensive application. The hierarchy introduced updates the DICE model for big data intensive application (Gómez et al., 2016).
Data Domains	This class encapsulates all the relevant concepts that characterize data based on the industries that produce it or need to extract information from it (Murthy et al., 2014). Specifically, this reuses and extends the big data taxonomy introduced by the Cloud Security Alliance (Murthy et al., 2014).

4. Illustrative Example

In this section, we provide an illustrative example that will help the reader better understand the applicability of the PrEstoCloud model outlined in the previous sections. This example considers a surveillance Big Data application (inspired by the Aditess use case scenario described in Deliverable 7.1) which collects and analyzes video streams from cameras installed on embedded systems. The Application leverages three processing layers: in the first layer, the embedded systems collect video streams and store them temporarily on local storage; when needed, these video streams are sent to the second layer which involves regional processing units (RPU's), i.e. small private clouds, for further analysis; finally, if the processing difficulty exceeds the capabilities of the RPU's, new processing VM's are spawned in a public cloud (constituting the third process layer). The architectural layout of the described application is depicted in Figure 6.

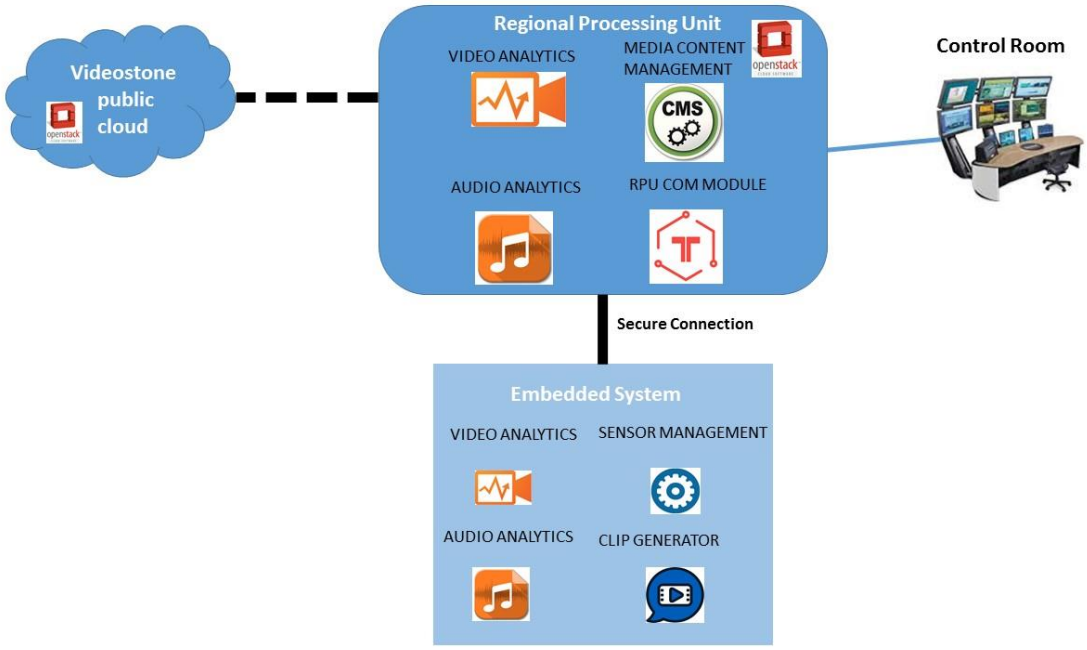

Figure 6: Aditess Use Case Scenario (PrEstoCloud, 2017a)

We make the assumption that the application is not designed and optimized for distributed execution, but there are classes and methods which can be executed in parallel by different hosting nodes for processing any incoming Big Data streams. Moreover, the application is programmed in Java, and consists of the following five classes (Table 4):

Table 4: Illustrative Java-based Application

Class Name	Short Description
Main	This class contains the core logic of the application. It contains the main method which is the entry point of execution, and auxiliary methods for the instantiation and communication with other classes.
Data	This class contains methods responsible of retrieving and storing surveillance camera data on regular intervals.
Audio_analytics	This class includes methods which can extract an audio stream from the video stream, and process it in order to detect unusual situations.
Video_analytics	This class includes methods which can process video streams to perform object and motion recognition tasks on them.
Communication	This class is responsible to handle all communication duties between the application processing elements.

The PrEstoCloud platform, can augment the processing choices for the application by defining different fragmentation policies. This means that different parts of the application, called fragments, can be executed in different processing VM's or edge devices, using certain fragmentation policies. A basic medium for the formulation of fragmentation policies is the annotations capability which -as mentioned above- permits the description of the processing intensity of the application, at method or class level. These annotations are subsequently consumed by a code introspector which parses the source code of the application and creates or updates a fragmentation policy file for each separate fragment.

Specifically, in List 1, we define a possible annotation structure, as part of the PrestoCloud library that mentions a policy file that includes the necessary placement requirments. In addition, it uses concepts from the PrEstoCloud model (Section 3) for allowing the application developer to denote aspects of the application fragment processing intensiveness and characteristics of the data streams that should be processed (e.g. CPULoad, DataVelocity). We note that this annotation structure may be expanded with additional attributes as the PrEstoCloud work progresses.

In List 2-List 6, we present an annotated general outline of the example application, according to the PrEstoCloud model that expoits the annotation structure presented in List 1.

List 1: Definition of PrestoFragmentation Annotation

```
package eu.prestocloud.annotations;

import java.lang.annotation.Retention;
import java.lang.annotation.RetentionPolicy;

@Retention(value = RetentionPolicy.RUNTIME)
public @interface PrestoFragmentation {
	enum MemoryLoad {
		LOW, MEDIUM, HIGH
	};

	enum CPULoad {
		LOW, MEDIUM, HIGH, VERY_HIGH
	};

	enum DataVelocity {
		LOW, MEDIUM, HIGH
	};

	enum StorageLoad {
		LOW, MEDIUM, HIGH
	};

	String policyFile();

	boolean onloadable();

	MemoryLoad memoryLoad();

	CPULoad cpuLoad();

	DataVelocity dataVelocity();

	StorageLoad storageLoad();

	String dependencyOn() default "";
	// ...
}
```

List 2: Annotating the Main Class

```
package com.surveillance.administrative;

import eu.prestocloud.annotations.PrestoFragmentation;
import eu.prestocloud.annotations.PrestoFragmentation.*;

@PrestoFragmentation(policyFile = "CloudSurveillance.frag_pol1", onloadable = false,
memoryLoad = MemoryLoad.MEDIUM, cpuLoad = CPULoad.LOW, dataVelocity = DataVelocity.LOW,
storageLoad = StorageLoad.LOW)
public class Main {
	// ...
}
```

List 3: Annotating the Data Class

```
package com.surveillance.administrative;

import eu.prestocloud.annotations.PrestoFragmentation;
import eu.prestocloud.annotations.PrestoFragmentation.*;

@PrestoFragmentation(policyFile = "CloudSurveillance.frag_pol1", onloadable = false,
memoryLoad = MemoryLoad.LOW, cpuLoad = CPULoad.LOW, dataVelocity = DataVelocity.LOW,
storageLoad = StorageLoad.MEDIUM)
public class Data {
	// ...
}
```

List 4: Annotating the AudioAnalytics Class and its Methods

```
package com.surveillance.analytics;

import eu.prestocloud.annotations.PrestoFragmentation;
import eu.prestocloud.annotations.PrestoFragmentation.*;

@PrestoFragmentation(policyFile = "CloudSurveillance.frag_pol2", onloadable = true,
memoryLoad = MemoryLoad.MEDIUM, cpuLoad = CPULoad.HIGH, dataVelocity =
DataVelocity.LOW, storageLoad = StorageLoad.LOW)
public class AudioAnalytics {
	@PrestoFragmentation(policyFile = "CloudSurveillance.frag_pol2", onloadable =
true, memoryLoad = MemoryLoad.MEDIUM, cpuLoad = CPULoad.MEDIUM, dataVelocity =
DataVelocity.LOW, storageLoad = StorageLoad.LOW)
	public boolean detectShout(AudioArtifact a) {
		// ...
		return false;
	}

	@PrestoFragmentation(policyFile = "CloudSurveillance.frag_pol2", onloadable =
true, memoryLoad = MemoryLoad.MEDIUM, cpuLoad = CPULoad.MEDIUM, dataVelocity =
DataVelocity.LOW, storageLoad = StorageLoad.LOW)
	public boolean detectGunshot(AudioArtifact a) {
		// ....
		return false;
	}
```

```
        public class AudioArtifact {

        }
}
```

List 5: Annotating the VideoAnalytics Class

```
package com.surveillance.analytics;

import eu.prestocloud.annotations.PrestoFragmentation;
import eu.prestocloud.annotations.PrestoFragmentation.*;

@PrestoFragmentation(policyFile = "CloudSurveillance.frag_pol3", onloadable = true,
memoryLoad = MemoryLoad.HIGH, cpuLoad = CPULoad.VERY_HIGH, dataVelocity =
DataVelocity.LOW, storageLoad = StorageLoad.MEDIUM)
public class VideoAnalytics {
        // ...
}
```

List 6: Annotating the Commincation Class

```
package com.surveillance.administrative;

import eu.prestocloud.annotations.PrestoFragmentation;
import eu.prestocloud.annotations.PrestoFragmentation.*;

@PrestoFragmentation(policyFile = "CloudSurveillance.frag_pol1", onloadable = false,
memoryLoad = MemoryLoad.MEDIUM,
cpuLoad = CPULoad.LOW, dataVelocity = DataVelocity.HIGH, storageLoad =
StorageLoad.HIGH, dependencyOn = "Data.class")
public class Communication {

}
```

We note that different annotations on method or classes that mention the same fragmentation policy, refer to shared placement requirements that will have as a result the certain application fragments to be placed under the same hosting resources. In the case that different processing requirements are expressed within code fragments of the same fragmentation policy, the code introspector implements a resolution policy (for example to choose the largest between all the requirements). The cloud application developer can directly edit the policy file, adding concrete requirement instances according to the PrEstoCloud Fragmentation Policy model requirements, and manually guide the mapping of the linguistic values processing requirements found in the annotations to concrete numeric requirements.

A Fragmentation policy file created by the above sample code (List 7), may involve the following:

List 7: CloudSurveillance.frag_pol1

```
BusinessGoal:
    MetricToMinimize: Cost
BudgetRequirement:
    CostThreshold: 1000€ TimePeriod: 1 month
HostingRequirement:
    hasNumberofCores: [1, 2]
    hasRAM: [8, 16]
    hasDisk: [1, infinity]
    hasBandwidth: [100000, 1000000]
EstimatedWorkload:
    CpuLoad: low    MemoryLoad: med
```

```
    DataVelocity: high
    StorageLoad: high
```

The above file is then added to a Fragmentation Policy Set which also defines a predilection of the Cloud Providers and the Edge Devices. In our example for simplicity, we assume that the Policy Set does not contain any predilection, so the information included in each fragmentation policy file is translated to specific nodes and relationships in the TOSCA Service Template file. The actual assignment of code fragments to processing nodes (servers) is performed using JPPF[11] which is a java framework facilitating distributed code execution. JPPF relies on a network of coordinator nodes (masters) and processing nodes (agents) to distribute and execute code.

The interpreter integrates JPPF (and any other software asset needed by the service) and definitions (such as node_definitions.yaml) in the Service Template as needed. The following ServiceTemplate.yaml[12] file (List 8) is produced by the Application Fragmentation & Deployment Recommender (the <APSC> tag indicates that the fields will be completed by the Application Placement & Scheduling Controller, since it is responsible for finding the optimal resources instances):

List 8: ServiceTemplate.yaml

```
tosca_definitions_version: tosca_simple_yaml_1_0
imports:
   - node_definitions: ./node_definitions.yaml
dsl_definitions:
   - frag_1: &frag_1
       id: 1
       name: main_processing_fragment
       onloadable: false
   - frag_2: &frag_2
       id: 2
       name: audio_analytics_fragment
       onloadable: true
   - frag_3: &frag_3
       id: 3
       name: video_analytics_fragment
       onloadable: true
metadata: { Optimize:cost,Budget:1000_EUR_month} #non-hosting requirements impacting
the deployment
description: The Service Template for the example application described above.
topology_template:
  node_templates:
    main_processing_server: #aggregates and deploys instances of Main.class,
Communication.class and Data.class, will undertake processing of fragment 1
      type: prestocloud.nodes.Compute
      capabilities:
        # Host container properties
        host:
         properties:
           num_cpus:  { in_range: [ 1,2 ] }
           disk_size: {greater_or_equal: 1 GB}
           mem_size:{greater_or_equal:  4 GB}
```

[11] http://www.jppf.org/

[12] We note that this is an exemplary use of TOSCA, while in follow up PrEstoCloud deliverables the configuration or even extension of TOSCA aspects for PrEstoCloud needs, will be defined.

```
            bandwidth_capacity: { in_range: [100 Mbps,1000 Mbps]} # Can be adapted as
needed
        attributes:
         service_provider: <APSC>
         provider_location: <APSC>
         proc_node:<APSC> #either VM flavor, or edge device type
         network_properties: <APSC>
  audio_analytics_server: #corresponds to Audio_analytics.class
      type:prestocloud.nodes.Compute
      capabilities:
        host:
         properties:
           num_cpus:  { in_range: [ 2, 4 ] }
           disk_size: {greater_or_equal: 1 GB}
           mem_size: {greater_or_equal: 2 GB}
        attributes:
         service_provider: <APSC>
         provider_location: <APSC>
         proc_node:<APSC> #either VM flavor, or edge device type
         network_properties: <APSC>
   video_analytics_server: #corresponds to Video_analytics.class
      type:prestocloud.nodes.Compute
      capabilities:
        # Host container properties
        host:
         properties:
           num_cpus:  { in_range: [ 4, 8 ] }
           disk_size: {greater_or_equal: 10 GB}
           mem_size: {greater_or_equal: 4 GB}
        attributes:
         service_provider: <APSC>
         provider_location: <APSC>
         proc_node:<APSC> #either VM flavor, or edge device type
         network_properties: <APSC>
  jppf_server: #the jppf master of the topology
    type: node.jppf.master
    properties:
        jppf-peers:[] #assuming only one server node here
    requirements:
         - dependency:
            node: main_server
  jppf_agent: #a jppf agent of the topology
    type: node.jppf.agent
    requirements:
        - host:
            capability: tosca.capabilities.Container
            node: main_processing_server
            relationship: tosca.relationships.HostedOn
    properties:
        jppf_master: jppf_server
        application_fragments: [frag_1]
  jppf_agent: #a jppf agent of the topology
    type: node.jppf.agent
    requirements:
        - host:
            capability: tosca.capabilities.Container
            node: audio_analytics_server
            relationship: tosca.relationships.HostedOn
    properties:
        jppf_master: jppf_server
        application_fragments: [frag_2]
```

```
  jppf_agent: #a jppf agent of the topology
    type: node.jppf.agent
    requirements:
        - host:
            capability: tosca.capabilities.Container
            node: video_analytics_server
            relationship: tosca.relationships.HostedOn
    properties:
        jppf_master: jppf_server
        application_fragments: [frag_3]
```

The contents of the TOSCA files imported by the main topology file are included in the appendix III below for reference. When the TOSCA file is completed by the APSC, it can be deployed, with the help of a TOSCA parser and a deployment engine of the control layer as it has been described in terms of deliverable D2.3. We note that the example TOSCA files provided above, will be further enhanced and extended to accommodate the full functionality of PrEstoCloud, as needed. Any extensions or improvements will be further discussed in the scope of Work Package 4.

5. Conclusions

This deliverable presented the PrEstoCloud model as a valuable artifact that allows application developers to annotate their Big Data cloud application code, highlight its meaningful fragmentations, declare any distribution constraints and express any hosting requirements per fragment, according to workload estimations. Essentially, this model constitutes the foundation to transparently handle candidate cloud resources from multiple providers and appropriate edge devices.

As detailed in the previous sections of this deliverable, the core of the PrEstoCloud model is the *Fragmentation Policy model* which includes all aspects necessary to identify application fragments and guide their placement over multi-cloud and edge resources. This core part is augmented by two vocabularies. The first one, named *Edge Resources Vocabulary*, was developed as part of the work performed in terms of WP3 and corresponds to an initial and extensible structured description of the concepts that can be used for expressing edge resources capabilities. The second vocabulary, the *Big Data Vocabulary*, includes an extensible taxonomy of concepts that can be used to express any relevant Big Data aspects and it was imported and re-used from the Melodic project.

The next steps of this work involve the development of the appropriate mechanisms to introspect code annotations and interpret them in a format suitable to be used as input for the two recommenders of the PrEstoCloud Meta-management layer (as part of the work in WP5). A parallel work, involves the description of TOSCA specification adaptations or extensions in order to be able to accommodate both Big Data related aspects and capabilities required for edge resources that may host Big Data application fragments (as part of the work in WP4).

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Appendix I – PrEstoCloud Fragmentation Policy Model

This appendix presents the serialization of the PrEstoCloud Fragmentation Policy Model in XMI. This will be also available in the PrEstoCloud code repository.


```
<?xml version="1.0" encoding="utf-8"?>
<xmi:XMI xmi:version="2.1" xmlns:uml="http://schema.omg.org/spec/UML/2.0"
xmlns:xmi="http://schema.omg.org/spec/XMI/2.1">
  <xmi:Documentation exporter="StarUML" exporterVersion="2.0" />
  <uml:Model xmi:id="AAAAAAFf/aSi9nabDb4=" xmi:type="uml:Model" name="RootModel">
    <packagedElement xmi:id="AAAAAAFF+qBWK6M3Z8Y=" name="Model" visibility="public"
    xmi:type="uml:Model">
      <packagedElement xmi:id="AAAAAAFfPitLhJXlSn8=" name="Application" visibility="public"
      isAbstract="false" isFinalSpecialization="false" isLeaf="false" xmi:type="uml:Class"
      isActive="false">
        <ownedMember xmi:id="AAAAAAFfPiu9spY3zGs=" name="0..*" visibility="public"
        xmi:type="uml:Association" isDerived="false">
          <ownedEnd xmi:id="AAAAAAFfPiu9spY4KRE=" visibility="public" isStatic="false"
          isLeaf="false" isReadOnly="false" isOrdered="false" isUnique="false"
          xmi:type="uml:Property" aggregation="none" isDerived="false" isID="false"
          type="AAAAAAFfPitLhJXlSn8=" />
          <ownedEnd xmi:id="AAAAAAFfPiu9spY5f3A=" name="1" visibility="public" isStatic="false"
          isLeaf="false" isReadOnly="false" isOrdered="false" isUnique="false"
          xmi:type="uml:Property" aggregation="none" isDerived="false" isID="false"
          type="AAAAAAFfPit2MpYOPO4=" />
          <memberEnd xmi:idref="AAAAAAFfPiu9spY4KRE=" />
          <memberEnd xmi:idref="AAAAAAFfPiu9spY5f3A=" />
        </ownedMember>
        <ownedMember xmi:id="AAAAAAFfPi8+t5l8GFo=" name="1" visibility="public"
        xmi:type="uml:Association" isDerived="false">
          <ownedEnd xmi:id="AAAAAAFfPi8+t5l9N/A=" visibility="public" isStatic="false"
          isLeaf="false" isReadOnly="false" isOrdered="false" isUnique="false"
          xmi:type="uml:Property" aggregation="none" isDerived="false" isID="false"
          type="AAAAAAFfPitLhJXlSn8=" />
          <ownedEnd xmi:id="AAAAAAFfPi8+t5l+yLo=" name="1..*" visibility="public" isStatic="false"
          isLeaf="false" isReadOnly="false" isOrdered="false" isUnique="false"
          xmi:type="uml:Property" aggregation="none" isDerived="false" isID="false"
          type="AAAAAAFfPi7ROJipx0Q=" />
          <memberEnd xmi:idref="AAAAAAFfPi8+t5l9N/A=" />
          <memberEnd xmi:idref="AAAAAAFfPi8+t5l+yLo=" />
        </ownedMember>
        <ownedMember xmi:id="AAAAAAFfPi9NKJng3Js=" name="1" visibility="public"
        xmi:type="uml:Association" isDerived="false">
```

```
    <ownedEnd xmi:id="AAAAAAFfPi9NKJnhvVw=" visibility="public" isStatic="false"
    isLeaf="false" isReadOnly="false" isOrdered="false" isUnique="false"
    xmi:type="uml:Property" aggregation="none" isDerived="false" isID="false"
    type="AAAAAAFfPitLhJXlSn8=" />
    <ownedEnd xmi:id="AAAAAAFfPi9NKZnigV4=" name="0..*" visibility="public" isStatic="false"
    isLeaf="false" isReadOnly="false" isOrdered="false" isUnique="false"
    xmi:type="uml:Property" aggregation="none" isDerived="false" isID="false"
    type="AAAAAAFfPi8E8pkVrFg=" />
    <memberEnd xmi:idref="AAAAAAFfPi9NKJnhvVw=" />
    <memberEnd xmi:idref="AAAAAAFfPi9NKZnigV4=" />
  </ownedMember>
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  xmi:type="uml:Property" aggregation="none" isDerived="false" isID="false" />
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  xmi:type="uml:Generalization" specific="AAAAAAFfPjrOMcTC1Hg="
  general="AAAAAAFfPjp57MICcSU=" />
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    xmi:type="uml:Property" aggregation="none" isDerived="false" isID="false"
    type="AAAAAAFfPjp57MICcSU=" />
    <memberEnd xmi:idref="AAAAAAFfP6QC+wY96+w=" />
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    type="AAAAAAFfPjp57MICcSU=" />
    <memberEnd xmi:idref="AAAAAAFfP6QVQAiZeC0=" />
    <memberEnd xmi:idref="AAAAAAFfP6QVQAiaSgM=" />
  </ownedMember>
  <ownedAttribute xmi:id="AAAAAAFfh+R91WVK6/g=" name="MetricToMaximize" visibility="public"
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    <ownedEnd xmi:id="AAAAAAFfPj7pJdRsuhs=" visibility="public" isStatic="false"
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    type="AAAAAAFfPjvyQ81DZwU=" />
    <ownedEnd xmi:id="AAAAAAFfPj7pJtRtBeM=" visibility="public" isStatic="false"
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```
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  type="AAAAAAFfPnFbh+jfC7s=" />
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```

```
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    type="AAAAAAFfPjvyQ81DZwU=" />
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  </ownedMember>
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  xmi:type="uml:Property" aggregation="none" isDerived="false" isID="false" />
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  isID="false" />
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isActive="false" />
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isActive="false" />
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```

```
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    type="AAAAAAFfPi8E8pkVrFg=" />
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    <memberEnd xmi:idref="AAAAAAFfgrlV+AefWgA=" />
  </ownedMember>
  <ownedMember xmi:id="AAAAAAFfgsRICZsmNVk=" visibility="public" xmi:type="uml:Association"
  isDerived="false">
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    type="AAAAAAFfgriPwPra1BQ=" />
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    type="AAAAAAFfgufzXAtKWag=" />
```

```
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    type="AAAAAAFfPjp57MICcSU=" />
    <memberEnd xmi:idref="AAAAAAFfgvOs3oU201I=" />
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```
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    type="AAAAAAFfpkdQ2YWaWCs=" />
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    type="AAAAAAFfpkdQ2YWaWCs=" />
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  </ownedMember>
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```

```
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      </packagedElement>
    </packagedElement>
  </uml:Model>
</xmi:XMI>
```

Appendix II – PrEstoCloud Edge Resources Vocabulary Serialization

This appendix presents an initial serialization of the Edge vocabulary in XMI. This will be also available in the PrEstoCloud code repository.

```
<?xml version="1.0" encoding="ascii"?>
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xmlns:mms="http://prestocloud-project.eu/model">
  <mms:MmsConcept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#1"
  id="a2a76c78-c50f-4c96-b6e2-c60a33e13dfa" uri="mms:a2a76c78-c50f-4c96-b6e2-c60a33e13dfa"
  name="PrEstoCloud Model" description="PrEstoCloud Model" topLevel="true">
    <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#2"
    id="bae11fff-2e34-4eb6-920e-255cceae926b"
    uri="http://prestocloud-project.eu/model#edge-resources-model" name="Edge Resources Model"
    description="Edge Resources Model">
      <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#3"
      id="915fb103-efb4-4b73-9195-cb9ee9d79b5f"
      uri="http://prestocloud-project.eu/model#edge-processing" name="Edge Processing"
      description="Edge Processing">
        <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#4"
        id="ee416ccf-ee85-4488-9901-e8c980018507"
        uri="http://prestocloud-project.eu/model#edge-cpu" name="Edge CPU" description="Edge CPU">
          <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#5"
          id="2c823b89-b8ab-4252-b5f1-7812487c9f36"
          uri="http://prestocloud-project.eu/model#hasCPUUtilization" name="hasCPUUtilization"
          description="hasCPUUtilization" rangeUri="xsd:string" />
          <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#6"
          id="6865a081-ebda-4a45-9245-eb24c14780ea"
          uri="http://prestocloud-project.eu/model#hasMIPs" name="hasMIPs" description="hasMIPs"
          rangeUri="xsd:string" />
          <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#7"
          id="a9b26860-c2f7-4115-a3f0-8dab2d45496d"
          uri="http://prestocloud-project.eu/model#hasMFLOPs" name="hasMFLOPs"
          description="hasMFLOPs" rangeUri="xsd:string" />
          <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#8"
          id="96254a8b-811c-4379-a2d0-f91abd248905"
          uri="http://prestocloud-project.eu/model#hasMinNumberofCores" name="hasMinNumberofCores"
          description="hasMinNumberofCores" rangeUri="xsd:string" />
          <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#9"
          id="e795246f-2817-4c0a-8d3a-8a2fb0c281f0"
          uri="http://prestocloud-project.eu/model#hasFrequency" name="hasFrequency"
```

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  description="hasFrequency" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#10"
  id="2903618a-d30b-45c4-84ca-193681df192c"
  uri="http://prestocloud-project.eu/model#hasMaxNumberofCores" name="hasMaxNumberofCores"
  description="hasMaxNumberofCores" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#11"
id="6f3d4a6a-322d-48b1-ab3d-5201dae2b0cf"
uri="http://prestocloud-project.eu/model#edge-ram" name="Edge RAM" description="Edge RAM">
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#12"
  id="4ab614a8-6db4-4f2e-9969-1be4b1647cb2"
  uri="http://prestocloud-project.eu/model#main-memory" name="Main Memory"
  description="Main Memory" />
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#13"
  id="06ce3cc5-180d-4c8c-b413-408e11f60350"
  uri="http://prestocloud-project.eu/model#shared-memory" name="Shared Memory"
  description="Shared Memory" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#14"
  id="e9aaf367-2e4f-473c-b57b-8111ae40cfbc"
  uri="http://prestocloud-project.eu/model#hasMinRAM" name="hasMinRAM"
  description="hasMinRAM" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#15"
  id="9a3a39f3-8f52-4fbf-a200-54ec13136739"
  uri="http://prestocloud-project.eu/model#hasMaxRAM" name="hasMaxRAM"
  description="hasMaxRAM" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#16"
  id="2ded9931-ae85-43d7-9629-475956733efc"
  uri="http://prestocloud-project.eu/model#hasUnit" name="hasUnit" description="hasUnit"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#17"
  id="eb23f434-8f4c-4603-aa04-b0012a2e38ea"
  uri="http://prestocloud-project.eu/model#hasFreeMemory" name="hasFreeMemory"
  description="hasFreeMemory" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#18"
  id="d05987f9-af55-44bd-87aa-8a325888873a"
  uri="http://prestocloud-project.eu/model#hasUsedMemory" name="hasUsedMemory"
  description="hasUsedMemory" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#19"
id="01b25a9c-4c5c-46b6-9f1f-7ca3ca36f4d3"
uri="http://prestocloud-project.eu/model#interfaces" name="Interfaces"
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description="Interfaces">
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#20"
  id="7250c3ee-2dbc-4949-91a1-b8f3cfbb1857"
  uri="http://prestocloud-project.eu/model#hasInterfacesResets" name="hasInterfacesResets"
  description="hasInterfacesResets" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#21"
  id="e458ad1a-1b9b-4b66-8992-7096d1d85dbe"
  uri="http://prestocloud-project.eu/model#hasInputDrops" name="hasInputDrops"
  description="hasInputDrops" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#22"
  id="e754de84-0c62-494f-8fc8-cdcfef80eb3a"
  uri="http://prestocloud-project.eu/model#hasInputErrors" name="hasInputErrors"
  description="hasInputErrors" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#23"
  id="0092ef8f-6d2e-4cc0-af84-39e7bb80e475"
  uri="http://prestocloud-project.eu/model#hasOutputDrops" name="hasOutputDrops"
  description="hasOutputDrops" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#24"
id="d18cc922-a33f-4164-b8bd-70b98a2acd5c" uri="http://prestocloud-project.eu/model#buffers"
name="Buffers" description="Buffers" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#25"
id="120f5cc8-c5fb-4210-ac2b-783c5400d000" uri="http://prestocloud-project.eu/model#stacks"
name="Stacks" description="Stacks" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#26"
id="fa45a813-154b-4e51-87f7-a5c71d31dac7"
uri="http://prestocloud-project.eu/model#controllers" name="Controllers"
description="Controllers" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#27"
id="2bcc0850-7965-4d17-b17a-aa7ef8f9ef1a" uri="http://prestocloud-project.eu/model#gpu"
name="GPU" description="GPU">
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#28"
  id="61ce53fb-2581-4014-8be1-bca1a4800b51"
  uri="http://prestocloud-project.eu/model#hasMinNumberofCores" name="hasMinNumberofCores"
  description="hasMinNumberofCores" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#29"
  id="8c0fe418-3de8-4397-b0e6-d6cc654ffabf"
  uri="http://prestocloud-project.eu/model#hasStartUsageDate" name="hasStartUsageDate"
  description="hasStartUsageDate" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#30"
  id="18fb672d-5bf1-402a-8821-dfc5a23d3933"
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    uri="http://prestocloud-project.eu/model#hasManufacturer" name="hasManufacturer"
    description="hasManufacturer" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#31"
    id="15a84184-c87d-48c0-812f-812178877d5f"
    uri="http://prestocloud-project.eu/model#hasGPUUtilization" name="hasGPUUtilization"
    description="hasGPUUtilization" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#32"
    id="dfa04707-89e5-444f-a66f-d865913f56de"
    uri="http://prestocloud-project.eu/model#hasClockSpeed" name="hasClockSpeed"
    description="hasClockSpeed" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#33"
    id="3c6a0ac1-2e5a-4c73-8af5-486beca87b5a"
    uri="http://prestocloud-project.eu/model#hasMFLOPs" name="hasMFLOPs"
    description="hasMFLOPs" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#34"
    id="4a893591-06cc-460f-bda9-d854657c8bfa"
    uri="http://prestocloud-project.eu/model#hasPEperCUs" name="hasPEperCUs"
    description="hasPEperCUs" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#35"
    id="73f27ac1-d9ac-4c6d-a6bd-b7a800a532a1"
    uri="http://prestocloud-project.eu/model#hasWarpSize" name="hasWarpSize"
    description="hasWarpSize" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#36"
    id="948ad28d-2d48-4145-aed0-49a75992d6ab"
    uri="http://prestocloud-project.eu/model#hasMaxConcurrentWorkgroups"
    name="hasMaxConcurrentWorkgroups" description="hasMaxConcurrentWorkgroups"
    rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#37"
    id="aea0af08-f992-4f68-8f5f-f0f0bca86c54"
    uri="http://prestocloud-project.eu/model#hasMemoryBandwidth" name="hasMemoryBandwidth"
    description="hasMemoryBandwidth" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#38"
    id="f33e9561-7a92-4f32-8732-33cc011dd821"
    uri="http://prestocloud-project.eu/model#hasMaxNumberofCores" name="hasMaxNumberofCores"
    description="hasMaxNumberofCores" rangeUri="xsd:string" />
  </concept>
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#39"
id="6d3a5f67-483e-4590-b966-344ad2869b61"
uri="http://prestocloud-project.eu/model#edge-storage" name="Edge Storage"
description="Edge Storage">
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  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#40"
  id="bc340e76-6d8b-4c88-82a9-b179824dc8e2"
  uri="http://prestocloud-project.eu/model#capacity" name="Capacity" description="Capacity">
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#41"
    id="5154f9db-1cb9-4212-aac5-1d5b7dc342d9"
    uri="http://prestocloud-project.eu/model#hasMinDisk" name="hasMinDisk"
    description="hasMinDisk" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#42"
    id="ccf19945-8d96-486c-964f-31643b976201"
    uri="http://prestocloud-project.eu/model#hasMaxDisk" name="hasMaxDisk"
    description="hasMaxDisk" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#43"
    id="383a9c3d-f00f-40c7-9a70-6054dba3e925"
    uri="http://prestocloud-project.eu/model#hasUnit" name="hasUnit" description="hasUnit"
    rangeUri="xsd:string" />
  </concept>
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#44"
  id="48ce3113-cb27-40ff-87ea-c4e55abd7b14"
  uri="http://prestocloud-project.eu/model#hasStorageUsage" name="hasStorageUsage"
  description="hasStorageUsage" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#45"
  id="9dfe215f-39be-4884-bff4-bc99c25f43bc"
  uri="http://prestocloud-project.eu/model#hasWriteTrhoughout" name="hasWriteTrhoughout"
  description="hasWriteTrhoughout" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#46"
  id="b85a6de7-e0f2-43a9-a02f-37c5ddc1bc86"
  uri="http://prestocloud-project.eu/model#hasReadThroughout" name="hasReadThroughout"
  description="hasReadThroughout" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#47"
id="51eb92b1-5672-4eaf-ab43-039e36a80cfb"
uri="http://prestocloud-project.eu/model#edge-network" name="Edge Network"
description="Edge Network">
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#48"
  id="6468571b-4e08-4e73-85f9-ef65520c3474"
  uri="http://prestocloud-project.eu/model#wireless-connection" name="Wireless Connection"
  description="Wireless Connection">
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#49"
    id="da7d8401-4bb0-4414-b937-61747bed4f3a"
    uri="http://prestocloud-project.eu/model#hasTelcoProvider" name="hasTelcoProvider"
    description="hasTelcoProvider" rangeUri="xsd:string" />
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  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#50"
  id="1f7c037e-8d38-4d22-aaa7-66dba0cf3d96"
  uri="http://prestocloud-project.eu/model#hasTransmissionSecurity"
  name="hasTransmissionSecurity" description="hasTransmissionSecurity"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#51"
  id="508fec08-a8c4-4842-bd5d-5ce323c619a5"
  uri="http://prestocloud-project.eu/model#usesBackhaulTopology"
  name="usesBackhaulTopology" description="usesBackhaulTopology" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#52"
  id="4475c9ac-8237-4e26-8b09-7270926a4c5e"
  uri="http://prestocloud-project.eu/model#usesBackhaulTechnology"
  name="usesBackhaulTechnology" description="usesBackhaulTechnology"
  rangeUri="xsd:string" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#53"
  id="4fea0258-50e0-4eb5-abda-36fb0e7bffe7" uri="http://prestocloud-project.eu/model#3G"
  name="3G" description="3G" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#54"
  id="0b3782a5-a763-4cc3-8b12-19b5e84ada05" uri="http://prestocloud-project.eu/model#4G"
  name="4G" description="4G" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#55"
  id="1205fcb4-3302-40d5-9268-a33851d6dda2"
  uri="http://prestocloud-project.eu/model#4G-LTE" name="4G LTE" description="4G LTE" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#56"
  id="85a76a9b-488b-4e83-8444-b7792dec2942" uri="http://prestocloud-project.eu/model#5G"
  name="5G" description="5G" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#57"
  id="0303b585-a774-4eee-919c-88ec2cb19a86" uri="http://prestocloud-project.eu/model#Wifi"
  name="Wifi" description="Wifi" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#58"
id="a322e5b3-adb1-4a5c-9ee3-29ee542bf6e5"
uri="http://prestocloud-project.eu/model#ethernet" name="Ethernet"
description="Ethernet" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#59"
id="a08f2889-01db-4a1c-b2dd-945b585555d5"
uri="http://prestocloud-project.eu/model#hasUploadSpeed" name="hasUploadSpeed"
description="hasUploadSpeed" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#60"
id="bb09a915-aa77-426f-a8cf-8248685f835b"
uri="http://prestocloud-project.eu/model#hasDownloadSpeed" name="hasDownloadSpeed"
```

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  description="hasDownloadSpeed" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#61"
  id="cdd5101e-a0a2-48cc-be2d-fb79c867c792"
  uri="http://prestocloud-project.eu/model#hasConnectionQuality" name="hasConnectionQuality"
  description="hasConnectionQuality" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#62"
  id="0fca6cba-d816-4325-a4f3-83a0dab5cbd3"
  uri="http://prestocloud-project.eu/model#hasLatestCarrierTransitions"
  name="hasLatestCarrierTransitions" description="hasLatestCarrierTransitions"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#63"
  id="a80ffa83-ca28-46e2-8774-a03229d97530"
  uri="http://prestocloud-project.eu/model#hasBandwidth" name="hasBandwidth"
  description="hasBandwidth" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#64"
id="825eafd0-8c65-4b4f-8289-efb5c97d56e3"
uri="http://prestocloud-project.eu/model#edge-sensors" name="Edge Sensors"
description="Edge Sensors">
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#65"
  id="2302ed07-ac28-42d5-9e86-50618ddf8714"
  uri="http://prestocloud-project.eu/model#edge-location" name="Edge Location"
  description="Edge Location">
    <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#66"
    id="7f797784-c847-4e25-8f40-474de5365ebe"
    uri="http://prestocloud-project.eu/model#network-location" name="Network Location"
    description="Network Location" />
    <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#67"
    id="ebfcd2d9-a07d-4bc0-8b1c-ff8d5e5c8658"
    uri="http://prestocloud-project.eu/model#gps-location" name="GPS Location"
    description="GPS Location">
      <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#68"
      id="77754030-a11d-47ec-acaf-aec3842d734c"
      uri="http://prestocloud-project.eu/model#hasElevation" name="hasElevation"
      description="hasElevation" rangeUri="xsd:string" />
      <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#69"
      id="4ac8ee73-1656-46bc-9b44-77aab8683dd8"
      uri="http://prestocloud-project.eu/model#hasSpeed" name="hasSpeed"
      description="hasSpeed" rangeUri="xsd:string" />
      <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#70"
      id="a16f9b21-2ed3-44c5-a4dc-613f4d92a779"
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    uri="http://prestocloud-project.eu/model#hasAccuracy" name="hasAccuracy"
    description="hasAccuracy" rangeUri="xsd:string" />
  </concept>
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#71"
id="ed9cf90a-bc03-483e-bd15-c775a8264b26" uri="http://prestocloud-project.eu/model#battery"
name="Battery" description="Battery">
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#72"
  id="10515770-66d3-4719-8ccd-f73cc3c7fef3"
  uri="http://prestocloud-project.eu/model#hasPowerLevel" name="hasPowerLevel"
  description="hasPowerLevel" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#73"
  id="17e7b34c-30ec-4182-9741-a71c41dc8c99"
  uri="http://prestocloud-project.eu/model#hasLatestCharging" name="hasLatestCharging"
  description="hasLatestCharging" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#74"
  id="45432fa1-7124-47a7-8c99-197dc5dd4d2f"
  uri="http://prestocloud-project.eu/model#hasLatestChargingDuraition"
  name="hasLatestChargingDuraition" description="hasLatestChargingDuraition"
  rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#75"
id="bdaccd39-ab3b-424c-87f5-6959bce3cd3b"
uri="http://prestocloud-project.eu/model#accelerometer" name="Accelerometer"
description="Accelerometer" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#76"
id="d48295b5-2d21-4da6-a194-2263188d07c2"
uri="http://prestocloud-project.eu/model#gyroscope" name="Gyroscope"
description="Gyroscope" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#77"
id="f12dfef8-d012-42c1-b09e-f2ccff09fd78"
uri="http://prestocloud-project.eu/model#magnetometer" name="Magnetometer"
description="Magnetometer" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#78"
id="7748088a-2808-49aa-8917-8b50485e603b"
uri="http://prestocloud-project.eu/model#proximity-sensor" name="Proximity Sensor"
description="Proximity Sensor" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#79"
id="d7d95b5b-fcb0-407e-a3d7-642477fb8ee3"
uri="http://prestocloud-project.eu/model#light-sensor" name="Light Sensor"
description="Light Sensor" />
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<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#80"
id="7ac5e2d3-58be-4559-ab55-925660f5f30e"
uri="http://prestocloud-project.eu/model#barometer" name="Barometer"
description="Barometer" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#81"
id="d5c473ff-0b7a-47b2-9677-86899b60e82c"
uri="http://prestocloud-project.eu/model#thermometer" name="Thermometer"
description="Thermometer" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#82"
id="77694010-a1e8-4898-abed-0df94d28e380"
uri="http://prestocloud-project.eu/model#air-humidity" name="Air humidity"
description="Air humidity" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#83"
id="95538b3e-a704-4bdb-83ff-04071e9cd98d" uri="http://prestocloud-project.eu/model#camera"
name="Camera" description="Camera">
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#84"
  id="772c33e5-3954-452e-923f-bdedd6a892c0"
  uri="http://prestocloud-project.eu/model#hasResolution" name="hasResolution"
  description="hasResolution" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#85"
  id="04f9e479-ef7a-47d4-ad7b-ce671e77118d"
  uri="http://prestocloud-project.eu/model#hasZoom" name="hasZoom" description="hasZoom"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#86"
  id="99e29af6-7b40-4969-9c15-6bcb758cacc5"
  uri="http://prestocloud-project.eu/model#hasSpectralRange" name="hasSpectralRange"
  description="hasSpectralRange" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#87"
  id="7470d047-1678-475a-aee5-c3eba8012bf7"
  uri="http://prestocloud-project.eu/model#hasStabilisation" name="hasStabilisation"
  description="hasStabilisation" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#88"
  id="7256ad7c-fc55-4511-9e3b-573fa0663a92"
  uri="http://prestocloud-project.eu/model#hasDistortionErrors" name="hasDistortionErrors"
  description="hasDistortionErrors" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#89"
id="cb1726bf-cea8-42c1-81d6-e152622dbaf2"
uri="http://prestocloud-project.eu/model#microphone" name="Microphone"
description="Microphone" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#90"
```

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  id="e1185745-5c3d-4a78-9692-9ff4e6e9f8f1"
  uri="http://prestocloud-project.eu/model#foreground-background-application"
  name="Foreground/BackgroundApplication" description="Foreground/BackgroundApplication" />
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#91"
  id="2a5c0710-b0e0-4b67-9aad-547aab639c5b"
  uri="http://prestocloud-project.eu/model#screen-state" name="ScreenState"
  description="Screen State" />
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#92"
  id="5f848c7a-ba88-4b5d-a03b-22d46ea9e2cc" uri="http://prestocloud-project.eu/model#voltage"
  name="Voltage" description="Voltage" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#93"
  id="28de24fe-9dbe-486a-972c-f4ac6c49c0a7"
  uri="http://prestocloud-project.eu/model#hasDeviceUniqueID" name="hasDeviceUniqueID"
  description="hasDeviceUniqueID" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#94"
id="005aeb75-693d-4ac4-a09d-2daf3925ab9c"
uri="http://prestocloud-project.eu/model#processing-mobility" name="Processing Mobility"
description="Processing Mobility">
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#95"
  id="9bea9fbc-9a32-44e7-91fa-ce6d31fefdc3"
  uri="http://prestocloud-project.eu/model#onloading" name="Onloading"
  description="Onloading">
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#96"
    id="739930f3-bf7d-4044-a847-148f869cc26a"
    uri="http://prestocloud-project.eu/model#hasStreamTransformationJob"
    name="hasStreamTransformationJob" description="hasStreamTransformationJob"
    rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#97"
    id="94f84727-9167-4f1d-a27b-93dc651db311"
    uri="http://prestocloud-project.eu/model#isADataSource" name="isADataSource"
    description="isADataSource" rangeUri="xsd:string" />
  </concept>
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#98"
  id="26e34c4c-1461-4a9c-8265-14504cdd3406"
  uri="http://prestocloud-project.eu/model#offloading" name="Offloading"
  description="Offloading">
    <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#99"
    id="c4f3fcab-1742-4920-b3a7-f8e65ef8d555"
    uri="http://prestocloud-project.eu/model#mobile-cloud-computing"
    name="MobileCloudComputing" description="Mobile Cloud Computing">
```

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  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#100"
  id="4c9199e4-90d6-47f6-af4f-c2a8a9cb9d1f"
  uri="http://prestocloud-project.eu/model#usesDistantCloudResources"
  name="usesDistantCloudResources" description="usesDistantCloudResources"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#101"
  id="9107f6ee-1c94-4870-8056-771497f1cf2e"
  uri="http://prestocloud-project.eu/model#usesCloudResourcesInProximity"
  name="usesCloudResourcesInProximity" description="usesCloudResourcesInProximity"
  rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#102"
id="15c8a2c7-8400-4d30-9814-8663ad3a483f"
uri="http://prestocloud-project.eu/model#mobile-edge-computing"
name="MobileEdgeComputing" description="Mobile Edge Computing">
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#103"
  id="e76829f3-c868-46c1-8700-3bc4daa9b89a"
  uri="http://prestocloud-project.eu/model#hasClosebyUserEquipment"
  name="hasClosebyUserEquipment" description="hasClosebyUserEquipment"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#104"
  id="5c01daa3-0e9a-4996-b8ef-51c8087c5983"
  uri="http://prestocloud-project.eu/model#hasWiFiConnection" name="hasWiFiConnection"
  description="hasWiFiConnection" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#105"
  id="b8e1dba1-c75f-405d-a311-b7106ed0f8e2"
  uri="http://prestocloud-project.eu/model#connectedToMECServer"
  name="connectedToMECServer" description="connectedToMECServer" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#106"
  id="6c03a62d-7641-44d9-9508-edc2f43fa16f"
  uri="http://prestocloud-project.eu/model#hasWiFiBandwidth" name="hasWiFiBandwidth"
  description="hasWiFiBandwidth" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#107"
  id="861a04b8-9d0c-4a19-9694-a1c2bae3f37c"
  uri="http://prestocloud-project.eu/model#hasOffset" name="hasOffset"
  description="hasOffset" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#108"
  id="e5f925d4-0c75-4014-99ab-7a7614d40052"
  uri="http://prestocloud-project.eu/model#hasBluetoothState" name="hasBluetoothState"
  description="hasBluetoothState" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#109"
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  id="68e8fb03-370a-4ad6-9852-7abc1b043056"
  uri="http://prestocloud-project.eu/model#hasCellSignalStrength"
  name="hasCellSignalStrength" description="hasCellSignalStrength"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#110"
  id="1fe35fde-70a4-4749-8065-35567158b613"
  uri="http://prestocloud-project.eu/model#hasWiFiSignalStrength"
  name="hasWiFiSignalStrength" description="hasWiFiSignalStrength"
  rangeUri="xsd:string" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#111"
  id="ff5b07b8-7608-41d8-a510-f3231be9d3d1"
  uri="http://prestocloud-project.eu/model#cloudlet" name="Cloudlet"
  description="Cloudlet" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#112"
id="f0be2d88-6e84-4b5a-8a50-d005a6fe3e72"
uri="http://prestocloud-project.eu/model#local-execution" name="Local Execution"
description="Local Execution" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#113"
id="fdb89c3b-5a22-4a6a-848d-c0e91d8425cf"
uri="http://prestocloud-project.eu/model#full-offloading" name="Full Offloading"
description="Full Offloading" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#114"
id="1710aadd-d8ae-4392-870d-93eb00c86e3f"
uri="http://prestocloud-project.eu/model#partial-offloading" name="Partial Offloading"
description="Partial Offloading">
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#115"
  id="a6488b50-46da-4122-af99-2f9bb2f094d6"
  uri="http://prestocloud-project.eu/model#hasdependencyOn" name="hasdependencyOn"
  description="hasdependencyOn" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#116"
id="01477359-c361-41fa-b68e-5aa8c3a6ba10"
uri="http://prestocloud-project.eu/model#data-offloading" name="DataOffloading"
description="Data Offloading" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#117"
id="3f091158-1e87-457d-a552-a764ba086524"
uri="http://prestocloud-project.eu/model#hasJob" name="hasJob" description="hasJob"
rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#118"
id="cce765ab-3360-4a67-b153-0559ef50cb11"
```

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    uri="http://prestocloud-project.eu/model#hasNonOffloadableParts"
    name="hasNonOffloadableParts" description="hasNonOffloadableParts"
    rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#119"
    id="9e5acc7e-6b3f-4cc6-a6bc-5f135f473a72"
    uri="http://prestocloud-project.eu/model#hasOffloadableParts" name="hasOffloadableParts"
    description="hasOffloadableParts" rangeUri="xsd:string" />
  </concept>
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#120"
  id="1435fa41-32f1-4e71-90c8-cf30d8539b56"
  uri="http://prestocloud-project.eu/model#hasMECServer" name="hasMECServer"
  description="hasMECServer" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#121"
  id="0ca2a714-fab1-43ec-a93b-4f83174562ae"
  uri="http://prestocloud-project.eu/model#hasExecutionLatency" name="hasExecutionLatency"
  description="hasExecutionLatency" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#122"
  id="f9ff7045-3930-4ea9-a8f7-87816b1dc7f7"
  uri="http://prestocloud-project.eu/model#hasEnergyconstraintForOffloading"
  name="hasEnergyconstraintForOffloading" description="hasEnergyconstraintForOffloading"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#123"
  id="7e713171-b3a4-4640-b497-9fa1cd87b32a"
  uri="http://prestocloud-project.eu/model#hasExecutionTime" name="hasExecutionTime"
  description="hasExecutionTime" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#124"
  id="61343977-674d-4995-abd4-f3ec6d5bbf6f"
  uri="http://prestocloud-project.eu/model#hasTransmissionTime" name="hasTransmissionTime"
  description="hasTransmissionTime" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#125"
id="9fa3c91f-c0e9-4402-bd48-6905b0886d4b"
uri="http://prestocloud-project.eu/model#edge-resource-mobility"
name="Edge Resource Mobility" description="Edge Resource Mobility">
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#126"
  id="18d38539-292c-4e02-bee4-477652c1272a" uri="http://prestocloud-project.eu/model#Low"
  name="Low" description="Low" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#127"
  id="c0b569eb-682c-4563-bf69-6a4edd7a4aa6" uri="http://prestocloud-project.eu/model#Medium"
  name="Medium" description="Medium" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#128"
```

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  id="53639a3a-0870-48fa-91e8-ca64652da797" uri="http://prestocloud-project.eu/model#High"
  name="High" description="High" />
</concept>
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#129"
id="92423189-dcd4-4549-9917-e0b035064721"
uri="http://prestocloud-project.eu/model#isADataSource" name="isADataSource"
description="isADataSource" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#130"
id="1870c54b-98ff-4b74-ad57-686b87f24eaf"
uri="http://prestocloud-project.eu/model#hasHardwareVersion" name="hasHardwareVersion"
description="hasHardwareVersion" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#131"
id="fcb9693a-d62e-4392-aea1-8efce391caee"
uri="http://prestocloud-project.eu/model#hasRunningConfig" name="hasRunningConfig"
description="hasRunningConfig" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#132"
id="8b20eb6d-765d-4151-893e-0a7b482691a0"
uri="http://prestocloud-project.eu/model#hasElapsedTimeSinceLastRestart"
name="hasElapsedTimeSinceLastRestart" description="hasElapsedTimeSinceLastRestart"
rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#133"
id="5a534a0e-f70d-4924-9e1d-db2adb3ce660"
uri="http://prestocloud-project.eu/model#hasCauseOfRestart" name="hasCauseOfRestart"
description="hasCauseOfRestart" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#134"
id="f871323d-dd95-47f2-822a-7330f8daa3e1"
uri="http://prestocloud-project.eu/model#hasTransmissionPower" name="hasTransmissionPower"
description="hasTransmissionPower" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#135"
id="95065277-9fe4-4966-b6be-9de84603802d"
uri="http://prestocloud-project.eu/model#hasManufacturer" name="hasManufacturer"
description="hasManufacturer" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#136"
id="dcffc0eb-1256-4b88-ba47-2f7fbf9196d7" uri="http://prestocloud-project.eu/model#hasOS"
name="hasOS" description="hasOS" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#137"
id="fa5ff3bf-aa08-41d4-8fa0-70a97976e242" uri="http://prestocloud-project.eu/model#hasUptime"
name="hasUptime" description="hasUptime" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#138"
id="bda3bdbc-9761-4235-b44e-5b6d055a9afb"
uri="http://prestocloud-project.eu/model#hasDeviceModel" name="hasDeviceModel"
```

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    description="hasDeviceModel" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#139"
    id="33ee9b4d-e508-45c0-9f6e-c77dc2b0bf2d"
    uri="http://prestocloud-project.eu/model#hasIdleTime" name="hasIdleTime"
    description="hasIdleTime" rangeUri="xsd:string" />
  </concept>
</mms:MmsConcept>
<mms:MmsConcept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#140"
id="a2a76c78-c50f-4c96-b6e2-c60a33e13dfa" uri="mms:a2a76c78-c50f-4c96-b6e2-c60a33e13dfa"
name="PrEstoCloud Model" description="PrEstoCloud Model" topLevel="true">
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#141"
  id="bae11fff-2e34-4eb6-920e-255cceae926b"
  uri="http://prestocloud-project.eu/model#edge-resources-model" name="Edge Resources Vocabulary"
  description="Edge Resources Vocabulary">
    <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#142"
    id="915fb103-efb4-4b73-9195-cb9ee9d79b5f"
    uri="http://prestocloud-project.eu/model#edge-processing" name="Edge Processing"
    description="Edge Processing">
      <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#143"
      id="01b25a9c-4c5c-46b6-9f1f-7ca3ca36f4d3"
      uri="http://prestocloud-project.eu/model#interfaces" name="Interfaces"
      description="Interfaces">
        <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#144"
        id="7250c3ee-2dbc-4949-91a1-b8f3cfbb1857"
        uri="http://prestocloud-project.eu/model#hasInterfacesResets" name="hasInterfacesResets"
        description="hasInterfacesResets" rangeUri="xsd:string" />
        <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#145"
        id="e754de84-0c62-494f-8fc8-cdcfef80eb3a"
        uri="http://prestocloud-project.eu/model#hasInputErrors" name="hasInputErrors"
        description="hasInputErrors" rangeUri="xsd:string" />
        <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#146"
        id="0092ef8f-6d2e-4cc0-af84-39e7bb80e475"
        uri="http://prestocloud-project.eu/model#hasOutputDrops" name="hasOutputDrops"
        description="hasOutputDrops" rangeUri="xsd:string" />
        <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#147"
        id="e458ad1a-1b9b-4b66-8992-7096d1d85dbe"
        uri="http://prestocloud-project.eu/model#hasInputDrops" name="hasInputDrops"
        description="hasInputDrops" rangeUri="xsd:string" />
      </concept>
      <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#148"
      id="120f5cc8-c5fb-4210-ac2b-783c5400d000" uri="http://prestocloud-project.eu/model#stacks"
```

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name="Stacks" description="Stacks" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#149"
id="fa45a813-154b-4e51-87f7-a5c71d31dac7"
uri="http://prestocloud-project.eu/model#controllers" name="Controllers"
description="Controllers" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#150"
id="6f3d4a6a-322d-48b1-ab3d-5201dae2b0cf"
uri="http://prestocloud-project.eu/model#edge-ram" name="Edge RAM" description="Edge RAM">
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#151"
  id="4ab614a8-6db4-4f2e-9969-1be4b1647cb2"
  uri="http://prestocloud-project.eu/model#main-memory" name="Main Memory"
  description="Main Memory" />
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#152"
  id="06ce3cc5-180d-4c8c-b413-408e11f60350"
  uri="http://prestocloud-project.eu/model#shared-memory" name="Shared Memory"
  description="Shared Memory" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#153"
  id="eb23f434-8f4c-4603-aa04-b0012a2e38ea"
  uri="http://prestocloud-project.eu/model#hasFreeMemory" name="hasFreeMemory"
  description="hasFreeMemory" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#154"
  id="e9aaf367-2e4f-473c-b57b-8111ae40cfbc"
  uri="http://prestocloud-project.eu/model#hasMinRAM" name="hasMinRAM"
  description="hasMinRAM" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#155"
  id="d05987f9-af55-44bd-87aa-8a325888873a"
  uri="http://prestocloud-project.eu/model#hasUsedMemory" name="hasUsedMemory"
  description="hasUsedMemory" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#156"
  id="9a3a39f3-8f52-4fbf-a200-54ec13136739"
  uri="http://prestocloud-project.eu/model#hasMaxRAM" name="hasMaxRAM"
  description="hasMaxRAM" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#157"
  id="2ded9931-ae85-43d7-9629-475956733efc"
  uri="http://prestocloud-project.eu/model#hasUnit" name="hasUnit" description="hasUnit"
  rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#158"
id="ee416ccf-ee85-4488-9901-e8c980018507"
uri="http://prestocloud-project.eu/model#edge-cpu" name="Edge CPU" description="Edge CPU">
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#159"
```

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  id="96254a8b-811c-4379-a2d0-f91abd248905"
  uri="http://prestocloud-project.eu/model#hasMinNumberofCores" name="hasMinNumberofCores"
  description="hasMinNumberofCores" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#160"
  id="2c823b89-b8ab-4252-b5f1-7812487c9f36"
  uri="http://prestocloud-project.eu/model#hasCPUUtilization" name="hasCPUUtilization"
  description="hasCPUUtilization" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#161"
  id="6865a081-ebda-4a45-9245-eb24c14780ea"
  uri="http://prestocloud-project.eu/model#hasMIPs" name="hasMIPs" description="hasMIPs"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#162"
  id="e795246f-2817-4c0a-8d3a-8a2fb0c281f0"
  uri="http://prestocloud-project.eu/model#hasFrequency" name="hasFrequency"
  description="hasFrequency" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#163"
  id="a9b26860-c2f7-4115-a3f0-8dab2d45496d"
  uri="http://prestocloud-project.eu/model#hasMFLOPs" name="hasMFLOPs"
  description="hasMFLOPs" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#164"
  id="2903618a-d30b-45c4-84ca-193681df192c"
  uri="http://prestocloud-project.eu/model#hasMaxNumberofCores" name="hasMaxNumberofCores"
  description="hasMaxNumberofCores" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#165"
id="d18cc922-a33f-4164-b8bd-70b98a2acd5c" uri="http://prestocloud-project.eu/model#buffers"
name="Buffers" description="Buffers" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#166"
id="2bcc0850-7965-4d17-b17a-aa7ef8f9ef1a" uri="http://prestocloud-project.eu/model#gpu"
name="GPU" description="GPU">
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#167"
  id="948ad28d-2d48-4145-aed0-49a75992d6ab"
  uri="http://prestocloud-project.eu/model#hasMaxConcurrentWorkgroups"
  name="hasMaxConcurrentWorkgroups" description="hasMaxConcurrentWorkgroups"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#168"
  id="f33e9561-7a92-4f32-8732-33cc011dd821"
  uri="http://prestocloud-project.eu/model#hasMaxNumberofCores" name="hasMaxNumberofCores"
  description="hasMaxNumberofCores" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#169"
  id="dfa04707-89e5-444f-a66f-d865913f56de"
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    uri="http://prestocloud-project.eu/model#hasClockSpeed" name="hasClockSpeed"
    description="hasClockSpeed" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#170"
    id="73f27ac1-d9ac-4c6d-a6bd-b7a800a532a1"
    uri="http://prestocloud-project.eu/model#hasWarpSize" name="hasWarpSize"
    description="hasWarpSize" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#171"
    id="61ce53fb-2581-4014-8be1-bca1a4800b51"
    uri="http://prestocloud-project.eu/model#hasMinNumberofCores" name="hasMinNumberofCores"
    description="hasMinNumberofCores" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#172"
    id="4a893591-06cc-460f-bda9-d854657c8bfa"
    uri="http://prestocloud-project.eu/model#hasPEperCUs" name="hasPEperCUs"
    description="hasPEperCUs" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#173"
    id="15a84184-c87d-48c0-812f-812178877d5f"
    uri="http://prestocloud-project.eu/model#hasGPUUtilization" name="hasGPUUtilization"
    description="hasGPUUtilization" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#174"
    id="18fb672d-5bf1-402a-8821-dfc5a23d3933"
    uri="http://prestocloud-project.eu/model#hasManufacturer" name="hasManufacturer"
    description="hasManufacturer" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#175"
    id="3c6a0ac1-2e5a-4c73-8af5-486beca87b5a"
    uri="http://prestocloud-project.eu/model#hasMFLOPs" name="hasMFLOPs"
    description="hasMFLOPs" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#176"
    id="aea0af08-f992-4f68-8f5f-f0f0bca86c54"
    uri="http://prestocloud-project.eu/model#hasMemoryBandwidth" name="hasMemoryBandwidth"
    description="hasMemoryBandwidth" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#177"
    id="8c0fe418-3de8-4397-b0e6-d6cc654ffabf"
    uri="http://prestocloud-project.eu/model#hasStartUsageDate" name="hasStartUsageDate"
    description="hasStartUsageDate" rangeUri="xsd:string" />
  </concept>
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#178"
id="825eafd0-8c65-4b4f-8289-efb5c97d56e3"
uri="http://prestocloud-project.eu/model#edge-sensors" name="Edge Sensors"
description="Edge Sensors">
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#179"
```

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id="bdaccd39-ab3b-424c-87f5-6959bce3cd3b"
uri="http://prestocloud-project.eu/model#accelerometer" name="Accelerometer"
description="Accelerometer" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#180"
id="825eafd0-8c65-4b4f-8289-efb5c97d56e3-112"
uri="http://prestocloud-project.eu/model#canbussensor" name="CAN Bus Sensor"
description="CAN Bus Sensor">
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#181"
  id="825eafd0-8c65-4b4f-8289-efb5c97d56e3-114"
  uri="http://prestocloud-project.eu/model#hasMessageID" name="hasMessageID"
  description="hasMessageID" rangeUri="xsd:positiveinteger" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#182"
id="5f848c7a-ba88-4b5d-a03b-22d46ea9e2cc" uri="http://prestocloud-project.eu/model#voltage"
name="Voltage" description="Voltage" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#183"
id="cb1726bf-cea8-42c1-81d6-e152622dbaf2"
uri="http://prestocloud-project.eu/model#microphone" name="Microphone"
description="Microphone" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#184"
id="2a5c0710-b0e0-4b67-9aad-547aab639c5b"
uri="http://prestocloud-project.eu/model#screen-state" name="ScreenState"
description="Screen State" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#185"
id="e1185745-5c3d-4a78-9692-9ff4e6e9f8f1"
uri="http://prestocloud-project.eu/model#foreground-background-application"
name="Foreground/BackgroundApplication" description="Foreground/BackgroundApplication" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#186"
id="7748088a-2808-49aa-8917-8b50485e603b"
uri="http://prestocloud-project.eu/model#proximity-sensor" name="Proximity Sensor"
description="Proximity Sensor" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#187"
id="d7d95b5b-fcb0-407e-a3d7-642477fb8ee3"
uri="http://prestocloud-project.eu/model#light-sensor" name="Light Sensor"
description="Light Sensor" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#188"
id="ed9cf90a-bc03-483e-bd15-c775a8264b26" uri="http://prestocloud-project.eu/model#battery"
name="Battery" description="Battery">
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#189"
  id="17e7b34c-30ec-4182-9741-a71c41dc8c99"
  uri="http://prestocloud-project.eu/model#hasLatestCharging" name="hasLatestCharging"
```

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  description="hasLatestCharging" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#190"
  id="45432fa1-7124-47a7-8c99-197dc5dd4d2f"
  uri="http://prestocloud-project.eu/model#hasLatestChargingDuraition"
  name="hasLatestChargingDuraition" description="hasLatestChargingDuraition"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#191"
  id="10515770-66d3-4719-8ccd-f73cc3c7fef3"
  uri="http://prestocloud-project.eu/model#hasPowerLevel" name="hasPowerLevel"
  description="hasPowerLevel" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#192"
id="d48295b5-2d21-4da6-a194-2263188d07c2"
uri="http://prestocloud-project.eu/model#gyroscope" name="Gyroscope"
description="Gyroscope" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#193"
id="95538b3e-a704-4bdb-83ff-04071e9cd98d" uri="http://prestocloud-project.eu/model#camera"
name="Camera" description="Camera">
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#194"
  id="7470d047-1678-475a-aee5-c3eba8012bf7"
  uri="http://prestocloud-project.eu/model#hasStabilisation" name="hasStabilisation"
  description="hasStabilisation" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#195"
  id="04f9e479-ef7a-47d4-ad7b-ce671e77118d"
  uri="http://prestocloud-project.eu/model#hasZoom" name="hasZoom" description="hasZoom"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#196"
  id="99e29af6-7b40-4969-9c15-6bcb758cacc5"
  uri="http://prestocloud-project.eu/model#hasSpectralRange" name="hasSpectralRange"
  description="hasSpectralRange" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#197"
  id="7256ad7c-fc55-4511-9e3b-573fa0663a92"
  uri="http://prestocloud-project.eu/model#hasDistortionErrors" name="hasDistortionErrors"
  description="hasDistortionErrors" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#198"
  id="772c33e5-3954-452e-923f-bdedd6a892c0"
  uri="http://prestocloud-project.eu/model#hasResolution" name="hasResolution"
  description="hasResolution" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#199"
id="f12dfef8-d012-42c1-b09e-f2ccff09fd78"
```

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uri="http://prestocloud-project.eu/model#magnetometer" name="Magnetometer"
description="Magnetometer" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#200"
id="2302ed07-ac28-42d5-9e86-50618ddf8714"
uri="http://prestocloud-project.eu/model#edge-location" name="Edge Location"
description="Edge Location">
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#201"
  id="ebfcd2d9-a07d-4bc0-8b1c-ff8d5e5c8658"
  uri="http://prestocloud-project.eu/model#gps-location" name="GPS Location"
  description="GPS Location">
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#202"
    id="4ac8ee73-1656-46bc-9b44-77aab8683dd8"
    uri="http://prestocloud-project.eu/model#hasSpeed" name="hasSpeed"
    description="hasSpeed" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#203"
    id="a16f9b21-2ed3-44c5-a4dc-613f4d92a779"
    uri="http://prestocloud-project.eu/model#hasAccuracy" name="hasAccuracy"
    description="hasAccuracy" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#204"
    id="77754030-a11d-47ec-acaf-aec3842d734c"
    uri="http://prestocloud-project.eu/model#hasElevation" name="hasElevation"
    description="hasElevation" rangeUri="xsd:string" />
  </concept>
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#205"
  id="7f797784-c847-4e25-8f40-474de5365ebe"
  uri="http://prestocloud-project.eu/model#network-location" name="Network Location"
  description="Network Location" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#206"
id="77694010-a1e8-4898-abed-0df94d28e380"
uri="http://prestocloud-project.eu/model#air-humidity" name="Air humidity"
description="Air humidity" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#207"
id="7ac5e2d3-58be-4559-ab55-925660f5f30e"
uri="http://prestocloud-project.eu/model#barometer" name="Barometer"
description="Barometer" />
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#208"
id="d5c473ff-0b7a-47b2-9677-86899b60e82c"
uri="http://prestocloud-project.eu/model#thermometer" name="Thermometer"
description="Thermometer" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#209"
```

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  id="28de24fe-9dbe-486a-972c-f4ac6c49c0a7"
  uri="http://prestocloud-project.eu/model#hasDeviceUniqueID" name="hasDeviceUniqueID"
  description="hasDeviceUniqueID" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#210"
id="6d3a5f67-483e-4590-b966-344ad2869b61"
uri="http://prestocloud-project.eu/model#edge-storage" name="Edge Storage"
description="Edge Storage">
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#211"
  id="bc340e76-6d8b-4c88-82a9-b179824dc8e2"
  uri="http://prestocloud-project.eu/model#capacity" name="Capacity" description="Capacity">
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#212"
    id="5154f9db-1cb9-4212-aac5-1d5b7dc342d9"
    uri="http://prestocloud-project.eu/model#hasMinDisk" name="hasMinDisk"
    description="hasMinDisk" rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#213"
    id="383a9c3d-f00f-40c7-9a70-6054dba3e925"
    uri="http://prestocloud-project.eu/model#hasUnit" name="hasUnit" description="hasUnit"
    rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#214"
    id="ccf19945-8d96-486c-964f-31643b976201"
    uri="http://prestocloud-project.eu/model#hasMaxDisk" name="hasMaxDisk"
    description="hasMaxDisk" rangeUri="xsd:string" />
  </concept>
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#215"
  id="48ce3113-cb27-40ff-87ea-c4e55abd7b14"
  uri="http://prestocloud-project.eu/model#hasStorageUsage" name="hasStorageUsage"
  description="hasStorageUsage" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#216"
  id="9dfe215f-39be-4884-bff4-bc99c25f43bc"
  uri="http://prestocloud-project.eu/model#hasWriteTrhoughout" name="hasWriteTrhoughout"
  description="hasWriteTrhoughout" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#217"
  id="b85a6de7-e0f2-43a9-a02f-37c5ddc1bc86"
  uri="http://prestocloud-project.eu/model#hasReadThroughout" name="hasReadThroughout"
  description="hasReadThroughout" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#218"
id="005aeb75-693d-4ac4-a09d-2daf3925ab9c"
uri="http://prestocloud-project.eu/model#processing-mobility" name="Processing Mobility"
description="Processing Mobility">
```

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<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#219"
id="26e34c4c-1461-4a9c-8265-14504cdd3406"
uri="http://prestocloud-project.eu/model#offloading" name="Offloading"
description="Offloading">
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#220"
  id="fdb89c3b-5a22-4a6a-848d-c0e91d8425cf"
  uri="http://prestocloud-project.eu/model#full-offloading" name="Full Offloading"
  description="Full Offloading" />
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#221"
  id="1710aadd-d8ae-4392-870d-93eb00c86e3f"
  uri="http://prestocloud-project.eu/model#partial-offloading" name="Partial Offloading"
  description="Partial Offloading">
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#222"
    id="a6488b50-46da-4122-af99-2f9bb2f094d6"
    uri="http://prestocloud-project.eu/model#hasdependencyOn" name="hasdependencyOn"
    description="hasdependencyOn" rangeUri="xsd:string" />
  </concept>
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#223"
  id="01477359-c361-41fa-b68e-5aa8c3a6ba10"
  uri="http://prestocloud-project.eu/model#data-offloading" name="DataOffloading"
  description="Data Offloading" />
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#224"
  id="c4f3fcab-1742-4920-b3a7-f8e65ef8d555"
  uri="http://prestocloud-project.eu/model#mobile-cloud-computing"
  name="MobileCloudComputing" description="Mobile Cloud Computing">
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#225"
    id="9107f6ee-1c94-4870-8056-771497f1cf2e"
    uri="http://prestocloud-project.eu/model#usesCloudResourcesInProximity"
    name="usesCloudResourcesInProximity" description="usesCloudResourcesInProximity"
    rangeUri="xsd:string" />
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#226"
    id="4c9199e4-90d6-47f6-af4f-c2a8a9cb9d1f"
    uri="http://prestocloud-project.eu/model#usesDistantCloudResources"
    name="usesDistantCloudResources" description="usesDistantCloudResources"
    rangeUri="xsd:string" />
  </concept>
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#227"
  id="f0be2d88-6e84-4b5a-8a50-d005a6fe3e72"
  uri="http://prestocloud-project.eu/model#local-execution" name="Local Execution"
  description="Local Execution" />
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#228"
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id="15c8a2c7-8400-4d30-9814-8663ad3a483f"
uri="http://prestocloud-project.eu/model#mobile-edge-computing"
name="MobileEdgeComputing" description="Mobile Edge Computing">
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#229"
  id="861a04b8-9d0c-4a19-9694-a1c2bae3f37c"
  uri="http://prestocloud-project.eu/model#hasOffset" name="hasOffset"
  description="hasOffset" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#230"
  id="b8e1dba1-c75f-405d-a311-b7106ed0f8e2"
  uri="http://prestocloud-project.eu/model#connectedToMECServer"
  name="connectedToMECServer" description="connectedToMECServer" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#231"
  id="68e8fb03-370a-4ad6-9852-7abc1b043056"
  uri="http://prestocloud-project.eu/model#hasCellSignalStrength"
  name="hasCellSignalStrength" description="hasCellSignalStrength"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#232"
  id="1fe35fde-70a4-4749-8065-35567158b613"
  uri="http://prestocloud-project.eu/model#hasWiFiSignalStrength"
  name="hasWiFiSignalStrength" description="hasWiFiSignalStrength"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#233"
  id="e5f925d4-0c75-4014-99ab-7a7614d40052"
  uri="http://prestocloud-project.eu/model#hasBluetoothState" name="hasBluetoothState"
  description="hasBluetoothState" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#234"
  id="e76829f3-c868-46c1-8700-3bc4daa9b89a"
  uri="http://prestocloud-project.eu/model#hasClosebyUserEquipment"
  name="hasClosebyUserEquipment" description="hasClosebyUserEquipment"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#235"
  id="6c03a62d-7641-44d9-9508-edc2f43fa16f"
  uri="http://prestocloud-project.eu/model#hasWiFiBandwidth" name="hasWiFiBandwidth"
  description="hasWiFiBandwidth" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#236"
  id="5c01daa3-0e9a-4996-b8ef-51c8087c5983"
  uri="http://prestocloud-project.eu/model#hasWiFiConnection" name="hasWiFiConnection"
  description="hasWiFiConnection" rangeUri="xsd:string" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#237"
  id="ff5b07b8-7608-41d8-a510-f3231be9d3d1"
  uri="http://prestocloud-project.eu/model#cloudlet" name="Cloudlet"
```

```
    description="Cloudlet" />
  </concept>
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#238"
  id="3f091158-1e87-457d-a552-a764ba086524"
  uri="http://prestocloud-project.eu/model#hasJob" name="hasJob" description="hasJob"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#239"
  id="9e5acc7e-6b3f-4cc6-a6bc-5f135f473a72"
  uri="http://prestocloud-project.eu/model#hasOffloadableParts" name="hasOffloadableParts"
  description="hasOffloadableParts" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#240"
  id="cce765ab-3360-4a67-b153-0559ef50cb11"
  uri="http://prestocloud-project.eu/model#hasNonOffloadableParts"
  name="hasNonOffloadableParts" description="hasNonOffloadableParts"
  rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#241"
id="9bea9fbc-9a32-44e7-91fa-ce6d31fefdc3"
uri="http://prestocloud-project.eu/model#onloading" name="Onloading"
description="Onloading">
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#242"
  id="94f84727-9167-4f1d-a27b-93dc651db311"
  uri="http://prestocloud-project.eu/model#isADataSource" name="isADataSource"
  description="isADataSource" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#243"
  id="739930f3-bf7d-4044-a847-148f869cc26a"
  uri="http://prestocloud-project.eu/model#hasStreamTransformationJob"
  name="hasStreamTransformationJob" description="hasStreamTransformationJob"
  rangeUri="xsd:string" />
</concept>
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#244"
id="0ca2a714-fab1-43ec-a93b-4f83174562ae"
uri="http://prestocloud-project.eu/model#hasExecutionLatency" name="hasExecutionLatency"
description="hasExecutionLatency" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#245"
id="7e713171-b3a4-4640-b497-9fa1cd87b32a"
uri="http://prestocloud-project.eu/model#hasExecutionTime" name="hasExecutionTime"
description="hasExecutionTime" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#246"
id="61343977-674d-4995-abd4-f3ec6d5bbf6f"
uri="http://prestocloud-project.eu/model#hasTransmissionTime" name="hasTransmissionTime"
```

```
  description="hasTransmissionTime" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#247"
  id="f9ff7045-3930-4ea9-a8f7-87816b1dc7f7"
  uri="http://prestocloud-project.eu/model#hasEnergyconstraintForOffloading"
  name="hasEnergyconstraintForOffloading" description="hasEnergyconstraintForOffloading"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#248"
  id="1435fa41-32f1-4e71-90c8-cf30d8539b56"
  uri="http://prestocloud-project.eu/model#hasMECServer" name="hasMECServer"
  description="hasMECServer" rangeUri="xsd:string" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#249"
id="9fa3c91f-c0e9-4402-bd48-6905b0886d4b"
uri="http://prestocloud-project.eu/model#edge-resource-mobility"
name="Edge Resource Mobility" description="Edge Resource Mobility">
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#250"
  id="53639a3a-0870-48fa-91e8-ca64652da797" uri="http://prestocloud-project.eu/model#High"
  name="High" description="High" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#251"
  id="18d38539-292c-4e02-bee4-477652c1272a" uri="http://prestocloud-project.eu/model#Low"
  name="Low" description="Low" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#252"
  id="c0b569eb-682c-4563-bf69-6a4edd7a4aa6" uri="http://prestocloud-project.eu/model#Medium"
  name="Medium" description="Medium" />
</concept>
<concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#253"
id="51eb92b1-5672-4eaf-ab43-039e36a80cfb"
uri="http://prestocloud-project.eu/model#edge-network" name="Edge Network"
description="Edge Network">
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#254"
  id="a322e5b3-adb1-4a5c-9ee3-29ee542bf6e5"
  uri="http://prestocloud-project.eu/model#ethernet" name="Ethernet"
  description="Ethernet" />
  <concept xmi:id="lhttp://prestocloud-project.eu/model#MmsConcept#255"
  id="6468571b-4e08-4e73-85f9-ef65520c3474"
  uri="http://prestocloud-project.eu/model#wireless-connection" name="Wireless Connection"
  description="Wireless Connection">
    <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#256"
    id="508fec08-a8c4-4842-bd5d-5ce323c619a5"
    uri="http://prestocloud-project.eu/model#usesBackhaulTopology"
    name="usesBackhaulTopology" description="usesBackhaulTopology" rangeUri="xsd:string" />
```

```
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#257"
  id="1f7c037e-8d38-4d22-aaa7-66dba0cf3d96"
  uri="http://prestocloud-project.eu/model#hasTransmissionSecurity"
  name="hasTransmissionSecurity" description="hasTransmissionSecurity"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#258"
  id="4475c9ac-8237-4e26-8b09-7270926a4c5e"
  uri="http://prestocloud-project.eu/model#usesBackhaulTechnology"
  name="usesBackhaulTechnology" description="usesBackhaulTechnology"
  rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#259"
  id="da7d8401-4bb0-4414-b937-61747bed4f3a"
  uri="http://prestocloud-project.eu/model#hasTelcoProvider" name="hasTelcoProvider"
  description="hasTelcoProvider" rangeUri="xsd:string" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#260"
  id="85a76a9b-488b-4e83-8444-b7792dec2942" uri="http://prestocloud-project.eu/model#5G"
  name="5G" description="5G" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#261"
  id="0b3782a5-a763-4cc3-8b12-19b5e84ada05" uri="http://prestocloud-project.eu/model#4G"
  name="4G" description="4G" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#262"
  id="0303b585-a774-4eee-919c-88ec2cb19a86" uri="http://prestocloud-project.eu/model#Wifi"
  name="Wifi" description="Wifi" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#263"
  id="1205fcb4-3302-40d5-9268-a33851d6dda2"
  uri="http://prestocloud-project.eu/model#4G-LTE" name="4G LTE" description="4G LTE" />
  <instance xmi:id="lhttp://prestocloud-project.eu/model#MmsConceptInstance#264"
  id="4fea0258-50e0-4eb5-abda-36fb0e7bffe7" uri="http://prestocloud-project.eu/model#3G"
  name="3G" description="3G" />
</concept>
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#265"
id="cdd5101e-a0a2-48cc-be2d-fb79c867c792"
uri="http://prestocloud-project.eu/model#hasConnectionQuality" name="hasConnectionQuality"
description="hasConnectionQuality" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#266"
id="0fca6cba-d816-4325-a4f3-83a0dab5cbd3"
uri="http://prestocloud-project.eu/model#hasLatestCarrierTransitions"
name="hasLatestCarrierTransitions" description="hasLatestCarrierTransitions"
rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#267"
id="a08f2889-01db-4a1c-b2dd-945b585555d5"
```

```
  uri="http://prestocloud-project.eu/model#hasUploadSpeed" name="hasUploadSpeed"
  description="hasUploadSpeed" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#268"
  id="bb09a915-aa77-426f-a8cf-8248685f835b"
  uri="http://prestocloud-project.eu/model#hasDownloadSpeed" name="hasDownloadSpeed"
  description="hasDownloadSpeed" rangeUri="xsd:string" />
  <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#269"
  id="a80ffa83-ca28-46e2-8774-a03229d97530"
  uri="http://prestocloud-project.eu/model#hasBandwidth" name="hasBandwidth"
  description="hasBandwidth" rangeUri="xsd:string" />
</concept>
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#270"
id="33ee9b4d-e508-45c0-9f6e-c77dc2b0bf2d"
uri="http://prestocloud-project.eu/model#hasIdleTime" name="hasIdleTime"
description="hasIdleTime" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#271"
id="dcffc0eb-1256-4b88-ba47-2f7fbf9196d7" uri="http://prestocloud-project.eu/model#hasOS"
name="hasOS" description="hasOS" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#272"
id="bda3bdbc-9761-4235-b44e-5b6d055a9afb"
uri="http://prestocloud-project.eu/model#hasDeviceModel" name="hasDeviceModel"
description="hasDeviceModel" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#273"
id="fcb9693a-d62e-4392-aea1-8efce391caee"
uri="http://prestocloud-project.eu/model#hasRunningConfig" name="hasRunningConfig"
description="hasRunningConfig" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#274"
id="fa5ff3bf-aa08-41d4-8fa0-70a97976e242" uri="http://prestocloud-project.eu/model#hasUptime"
name="hasUptime" description="hasUptime" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#275"
id="8b20eb6d-765d-4151-893e-0a7b482691a0"
uri="http://prestocloud-project.eu/model#hasElapsedTimeSinceLastRestart"
name="hasElapsedTimeSinceLastRestart" description="hasElapsedTimeSinceLastRestart"
rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#276"
id="1870c54b-98ff-4b74-ad57-686b87f24eaf"
uri="http://prestocloud-project.eu/model#hasHardwareVersion" name="hasHardwareVersion"
description="hasHardwareVersion" rangeUri="xsd:string" />
<property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#277"
id="f871323d-dd95-47f2-822a-7330f8daa3e1"
uri="http://prestocloud-project.eu/model#hasTransmissionPower" name="hasTransmissionPower"
```

```
      description="hasTransmissionPower" rangeUri="xsd:string" />
      <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#278"
      id="5a534a0e-f70d-4924-9e1d-db2adb3ce660"
      uri="http://prestocloud-project.eu/model#hasCauseOfRestart" name="hasCauseOfRestart"
      description="hasCauseOfRestart" rangeUri="xsd:string" />
      <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#279"
      id="92423189-dcd4-4549-9917-e0b035064721"
      uri="http://prestocloud-project.eu/model#isADataSource" name="isADataSource"
      description="isADataSource" rangeUri="xsd:string" />
      <property xmi:id="lhttp://prestocloud-project.eu/model#MmsProperty#280"
      id="95065277-9fe4-4966-b6be-9de84603802d"
      uri="http://prestocloud-project.eu/model#hasManufacturer" name="hasManufacturer"
      description="hasManufacturer" rangeUri="xsd:string" />
    </concept>
  </mms:MmsConcept>
</xmi:XMI>
```

Appendix III – Auxiliary TOSCA files for Illustrative Example

Node_definitions.yaml

```
tosca_definitions_version: tosca_simple_yaml_1_0

imports:
    -  application_fragment: ./application_fragment.yaml
node_types:

  prestocloud.nodes.Compute
    description:
        A TOSCA description of the main processing nodes in this example
    derived_from: tosca.nodes.Compute
    properties:
      bandwidth_capacity:
         type: integer
    attributes:
      service_provider:
         type: string
      provider_location:
         type: string
      proc_node_id:
         type: string
      network_properties:
         type: list
         entry_schema:
         description: The network properties of the processing node
         type: string

  node.jppf.agent:
    description:
       A TOSCA description of a JPPF processing node
    derived_from: tosca.nodes.Compute
    properties:
      jppf-master:
        type: string #ip address
      application_fragments:
         type: list
         entry_schema:
         description: The application fragments the node can undertake to process
         type: ApplicationFragment #defined elsewhere in application_fragment.yaml

  node.jppf.master:
    description:
       A TOSCA description of a JPPF master node, also containing the peer nodes with
which it can federate if needed.
   derived_from: tosca.nodes.Compute
   properties:
       jppf-peers:
         type: list
         entry_schema:
           description: The application fragments the node can undertake to process
           type: node.jppf.master
```

application_fragment.yaml

```
tosca_definitions_version: tosca_simple_yaml_1_0

data_types:
 ApplicationFragment:
  derived_from: tosca.datatypes.Root
  properties:
         id:
            type: integer
         name:
            type: String
         onloadable:
            type: boolean
```