MARVEL

An overview of standards involved in smart cities in the context of MARVEL

Cities are dynamic hubs of growth that make use of Information and Communication Technology (ICT) to optimise the services of its urban population. MARVEL project aims to empower smart cities through the application of AI technology to improve citizen services while ensuring security for individuals and their personal data.

MARVEL partners

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INFINEON TECHNOLOGIES AG (IFAG), established in AM CAMPEON 1-15, NEUBIBERG 85579, Germany

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SPHYNX TECHNOLOGY SOLUTIONS AG (STS), established in C/O ASVITO AG CHOLLERSTRASSE 35, ZUG 6300, Switzerland

COMUNE DI TRENTO (MT), established in BELENZANI 19, TRENTO 38122, Italy

UNIVERZITET U NOVOM SADU FAKULTET TEHNICKIH NAUKA (UNS), established in TRG DOSITEJA OBRADOVICA 6, NOVI SAD 21000, Serbia

INFORMATION TECHNOLOGY FOR MARKET LEADERSHIP (ITML), established in KATECHAKI 22, ATHINA 115 25, Greece

GREENROADS LIMITED (GRN), established in 21 TRIQ IL MELISSA, MGARR MGR 221, Malta

ZELUS IKE (ZELUS), established in TATOIOY 92, METAMORFOSI - ATHINA 14452, Greece

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Executive summary

Since industrialization there has been an increase in rural-to-urban migration searching for improved living standards. Urban areas became a point of attraction to economies and society providing access to multiple and diverse services as well as an improved living environment. To keep up with the needs and services of the people living there, cities have to be continuously growing and changing, resulting in a constant challenge for the development of a city.

Technological innovations, in particular urban technology, helped mitigate some challenges in the development of metropolitan areas, resulting in the development of more efficient cities. Advances in networks, microelectronics and digital electronic technologies as well as the emergence of more digital solutions led to significant improvements in the quality of life of the urban residents. More recently, the introduction of newest digital technologies, such as Internet of Things (IoT), Artificial Intelligence (AI) or Big Data (BD) has transformed traditional cities into what we know as smart cities.

A Smart city can be defined as a system that uses Information and Communication Technology (ICT) to meet the requirements of its urban population. These requirements include optimising energy and utility management, environmental protection, improved mobility and transport, among other services. All this, while prioritising security and data privacy.

To accomplish those requirements it is important to follow strict norms and certain ways of working, providing compatibility and ensuring correct process development. Standards are made for these particular reasons, providing best practices emphasising safety and quality. Standards are documents with detailed descriptions defining requirements, production processes and services. These specifications are made through a consensus with industry and market actors. The development of standards for smart cities plays a crucial part in shaping the cities of the future, with the fixed goal of improving the quality of life of its urban residents. One challenge of developing standards in the context of smart cities is that they cover a wide framework of technologies and data-driven solutions. These technologies can belong to AI, software development, information security, and privacy standards, among others.

The European project on multimodal extreme scale data analytics for smart cities environments, MARVEL for short, aims at empowering smart cities authorities to better support their citizens. The goal of this document is to present standards that have been applied during the development of MARVEL and their role played in the project. The document is organised as follows, firstly a short introduction of the MARVEL project is given. Then the goals and outcomes achieved during the lifetime of the project are presented. Secondly, the relevant project's contributions to standardisation are discussed. Finally, the different standards for each of the utilised technologies are listed, giving a short description for each or them.
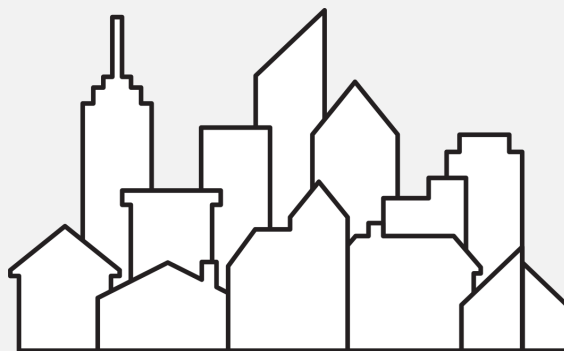
MARVEL project

The Smart City paradigm aims to support new forms of monitoring and managing resources, as well as to provide situational awareness in decision-making fulfilling the objective of servicing the citizen while ensuring that it meets the needs of present and future generations with respect to economic, social, and environmental aspects. It considers the city as a complex and dynamic system involving different interconnected spatial, social, economic, and physical processes subject to temporal changes and continually modified by human actions. Big Data, fog, and edge computing technologies have significant potential in various scenarios, considering each city's individual tactical strategy. However, one critical aspect is to encapsulate the complexity of a city and support accurate, cross-scale, and in-time predictions based on the ubiquitous spatiotemporal data of high-volume, high-velocity, and of high-variety.

To address this challenge, MARVEL delivers a disruptive Edge-to-Fog-to-Cloud (E2F2C) ubiquitous computing framework that enables multimodal perception and intelligence for audio-visual scene recognition and event detection in a smart city environment. MARVEL collects, analyses and data-mine multimodal audio-visual data streams of a Smart City and helps decision-makers to improve the quality of life and services to the citizens. This is achieved via (i) fusing large-scale distributed multimodal audio-visual data in real-time; (ii) achieving fast time-to-insights; (iii) supporting automated decision-making at all levels of the E2F2C stack; and (iv) delivering a personalised Federated Learning (FL) approach, where joint multimodal representations and models are co-designed and improved continuously through privacy-aware sharing of personalised fog and edge models of all interested parties. Nevertheless, the project achieves these goals without violating ethical and privacy limits in an Artificial Intelligence (AI)-responsible manner.

MARVEL OBJECTIVES

MARVEL objectives are as follows:

1. Leverage innovative technologies for data acquisition, management, and distribution to develop a privacy-aware engineering solution for revealing valuable and hidden societal knowledge in a smart city environment;
2. Deliver AI-based multimodal perception and intelligence for audio-visual scene recognition, event detection, and situational awareness in a smart city environment;
3. Break technological silos, converge very diverse and novel engineering paradigms, and establish a distributed and secure Edge-to-Fog-to-Cloud (E2F2C) ubiquitous computing framework in the big data value chain;
4. Realise societal opportunities in a smart city environment by validating tools and techniques in real-world settings;
5. Foster the European Data Economy vision and create new scientific and business opportunities by offering the MARVEL Data Corpus as a free service.

MARVEL OUTCOMES

Big Data holds the potential to revolutionise the way Europe addresses major societal challenges, spanning from healthcare efficiency and social security to public safety, well-being, and transportation. The MARVEL project aims to not only accelerate the adoption of Big Data technologies but also empower citizens to become more informed, educated, and engaged in the digital landscape. By doing so, MARVEL has significantly impacted the acquisition of digital skills and filled the growing need for high-value jobs in data science, AI, and software engineering. By harnessing the butterfly effect and leveraging data more strategically, MARVEL has unlocked societal opportunities in the Smart City domain. The project's focus on efficient proactive processing and reliable predictions using audio and video content analysis allows for near-real-time responses to incidents occurring in various city locations. This, in turn, leads to the provision of smart services related to public safety, well-being, and transportation in urban environments. Furthermore, MARVEL has penetrated the market with a comprehensive technology framework that leverages big data and extreme-scale analytics to capture the essence of cities, offering insights and predictive capabilities for major outdoor events.

How MARVEL has penetrated the market can be seen with the multiple use cases implemented with the three MARVEL pilots, which are: the municipality of Trento (Italy), the municipality of Malta and the university of Novi Sad (Serbia). In Trento there are four implemented use cases, on the field of crowd areas. The use case *monitoring of crowd areas* (MT1) aims to identify relevant areas with significant crowd presence in order to detect unusual crowd movements. The next use case is *detecting criminal and antisocial behaviours* (MT2), where the system triggers an alarm when a criminal or anti-social behaviour is detected. Another use case that detects threats or suspicious activities is the *monitoring of parking places* (MT3), where cameras and microphones are used to identify potential threats. Finally, the *analysis of a specific area* (MT4) use case, provides various functionalities, including person and vehicle counting, trajectory calculation and detection of notable events. In the municipality of Malta there are also four implemented use cases, all based on the study of traffic in a city to increase safety on urban roads. More specifically *safer roads* (GRN1) use case detects cyclists and pedestrians to alert other vehicle drivers of their presence in real time, *road user behaviour* (GRN2) use case detects actions to compare road user behaviour before and after an educational campaign, *traffic conditions and anomalous events* (GRN3) use case monitors traffic conditions and detects anomalous events such as traffic jams, accidents, etc. The last one is *junction traffic trajectory collection* (GRN4) use case, it is used to collect long term data on trajectories to allow infrastructure providers to make data driven choices. The last pilot was implemented in the University of Novi Sad, there were two use cases. The first one called *drone experiment* (UNS1), performed surveillance of large public events and the monitoring of the behaviour of the crowds through the utilisation of drones. The second use case, *localising audio events in crowds* (UNS2), consisted of the use of microphone array boards for monitoring public events by detecting target sound events and finding the direction of the sound propagation, helping to localise anomalous events in crowds.

In addition to empowering stakeholders and the general public with big data and extreme-scale analytics, MARVEL seeks to drive economic growth and job creation. The project has advanced big data analytics to the next evolutionary level, utilising complementary processing steps from diverse data sources for early anomaly detection and event identification in demanding urban environments. This contributes to the upgrade and future transformation of the Smart City domain, boosting industries and Small and Medium-sized Enterprises (SMEs) with increased market share, and creating more job opportunities for high-skilled data professionals.

Relevant MARVEL results for standardisation

To improve the visibility, usability and acceptance of MARVEL results, MARVEL is aligning several aspects to different initiatives that are getting traction among wide communities or are becoming de-facto standards in their respective fields. These efforts focused on elements of the MARVEL framework such as the system architecture or the data models to exchange and store information.

MARVEL Architecture

MARVEL use cases pipelines and the system architecture that supports them have been mapped to follow the DataBench[3] approach. In the scope of the projects funded under the Big Data Value PPP1[1], the project DataBench devised what it is called a generic Big Data Architectural Blueprint. This blueprint is mapped to the main four steps defined in DataBench for a typical data value chain, namely:

I. **Data Acquisition/Collection**: covering aspects related to data ingestion, extraction, processing, streaming for different data types.
II. **Data Storage/Preparation**: referring to storage, retrieval/access/queries, data protection, data curation, data fusion, and publication processes.
III. **Data Analytics/ML**: including AI, ML, DL, data processing for analysis, training.
IV. **Data Visualisation, Action/Interaction**: covering aspects about visualisation, data presentation, interaction with humans and other systems.

The Big Data Architectural blueprint provides a sequence of steps that are in principle generic enough to fit most of the big data and AI systems and applications. Note that the blueprint is abstract and can be applied to different data types. For instance, processing Audio-Visual (AV) data follows similar steps to processing textual or structured data, although the technologies involved might not be the same. Therefore, the mapping of the blueprint to a generic architecture might stay at an abstract level, but it might be more specific when dealing with concrete use cases and data types. The blueprint has been customised by several EU-funded projects to map their own architecture and use cases, therefore providing a clear link among different initiatives and a standard way of the technological choices selected in each project.
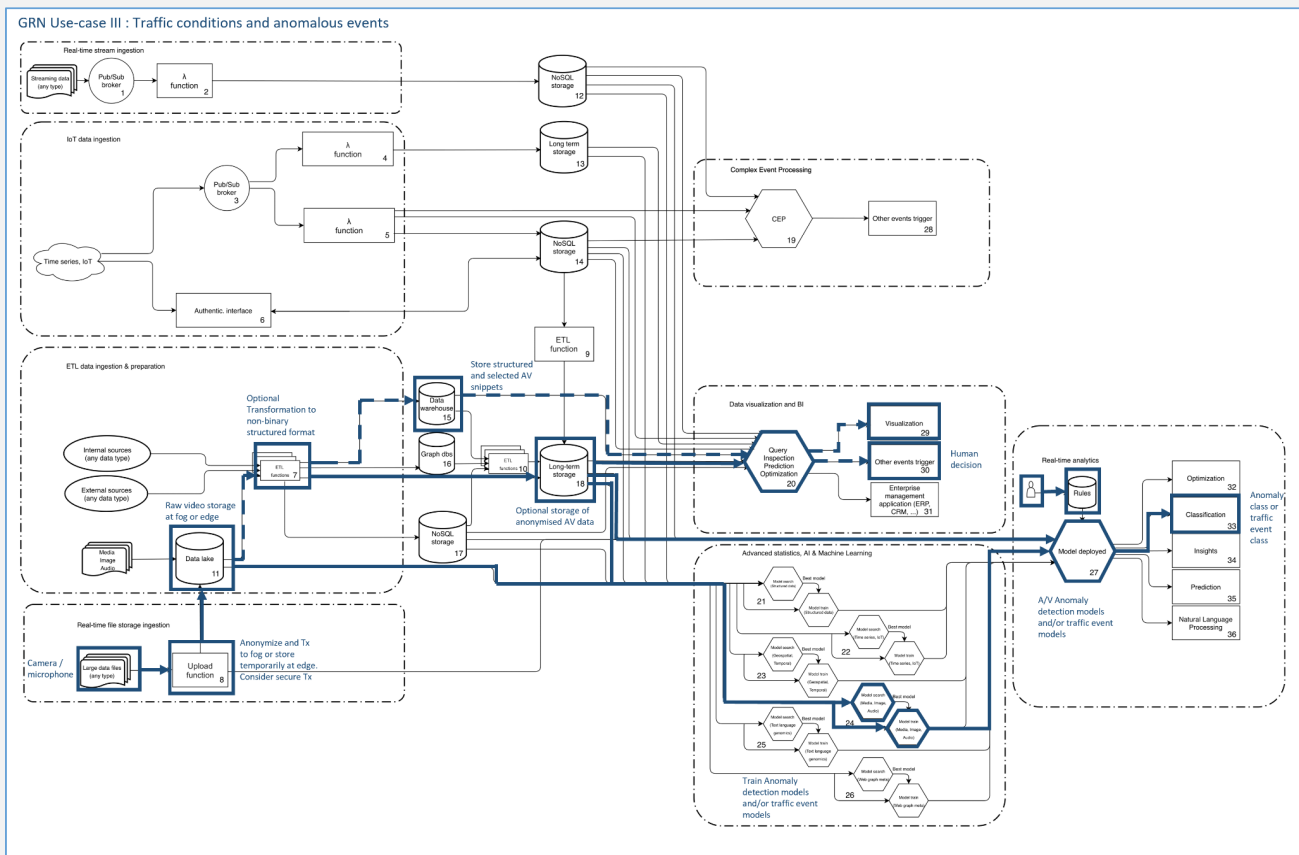

Figure 1. Specification of the generic Big Data and AI pipeline blueprint for the GRN3 use case: Traffic conditions and anomalous events.

An example of one of the MARVEL use cases is shown in Figure 1. The figure illustrates the result of mapping the GRN3 use case pipelines to the DataBench. In this use case, traffic conditions, such as light or heavy traffic, and anomalous events, such as anomalous queue lengths and roadside breakdown are detected in the AV data. This use case can be deployed in real-time, for example, to alert traffic control room personnel of anomalous events and can also be used offline to collect statistics on anomalous events. The pipeline for a real-time application (after the model is trained) is as follows:

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[1] Big Data Value Public Private Partnership, https://ec.europa.eu/digital-single-market/en/big-data-value-public-private-partnership

- The data is extracted by a camera and microphone, anonymised (8) and transmitted to raw video storage (11) which could be at the fog or edge.
- This is then loaded to Extract, Transform and Load (ETL) data ingestion and preparation (7) where an optional transformation to a non-binary structured format can be made.
- From there the data is stored and selected into AV snippets (15) and transferred to (20) where the data is inspected and can then be visualised (29) or trigger an event (30) such that a human is alerted.
- From (7) the data can be transferred to (18) where there is the option of storing the anonymised AV data which can be used to train the model (24), passed to (20) for data visualisation and BI (Business Intelligence) block or to (27) for real-time analytics.

DATA MODELS IN MARVEL

In the case of data models used in MARVEL for storage and handling of data, the approach has been to reuse and adapt some of the models of the Smart Data Models (SDM) program to MARVEL needs. The SDM is a joint collaborative program led by the FIWARE Foundation, TM Forum and IUDX, aiming at providing multisector, agile, standardised, free and open-licensed data models based on actual use cases and open standards. The SDM initiative constitutes a further step in achieving common data spaces, publicly available contrastive data models, supporting interoperability. All data models are public and royalty-free specifications, including JSON Schemas and documentation, hosted in GitHub and classified as cross-sector and vertical. SDM is particularly active in the smart cities domain, AI and Internet of Things (IoT) since its inception.

MARVEL has examined and particularised several of the SDM models to the needs of the use cases, taking the models as baseline and extending them when appropriate. In particular, MARVEL is using the data models for *Camera*, to describe all AV sources, and *MLModel* to describe the MARVEL AI models, as well as three other models to describe events as results of the AI inference:

- *Alert*, to describe MARVEL inference results produced by the AI models that have to alert the uses of a specific event.
- *Anomaly*, for events detected by the AI models that correspond to an anomaly.
- *MediaEvent*, for any other event result of the inference that does not require specific treatment.

These data models have been extended with MARVEL specific attributes, such as specific timestamps for benchmarking purposes. The MARVEL framework allows the different AI models to output their inference results in any format, and provides the means to transform these data to the SDM-compliant data models. The inference data is then further analysed and stored following SDM-compliant format. This ensures the interoperability of MARVEL with other initiatives that follow a similar approach, such as the smart cities implementing solutions listed as members under the Open & Agile Smart Cities (OASC) organisation.

AI PERFORMANCE EVALUATION

Currently, there are no standards related to technical benchmarking audio or video content analysis in smart cities. Similarly, there are no standardised evaluation protocols for the performance of AI-based content analysis components in smart city applications.

MARVEL Data Corpus provides a good basis to fill this void by providing open data from real smart city use cases. The data provided in the Corpus is ideal for creating benchmarks for specific tasks related to audio-visual content analysis in the context of a smart city. The Corpus contains anonymized video and audio data captured from multiple locations, and part of the data is provided with manually produced reference annotations for various smart city applications such as sound event detection, vehicle recognition, and crowd counting. In addition to the data, performance evaluation setups used in MARVEL to assess the performance[2] of analysis components can be used as bases for application-specific benchmarks in the future.

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[2] Project deliverable D5.5 "Technical evaluation and progress against benchmarks", https://www.marvel-project.eu/deliverables/

MARVEL Standardisation White Paper

MARVEL CONTRIBUTIONS TO STANDARDISATION-RELATED INITIATIVES

Project partner *Consiglio Nazionale delle Ricerche* (CNR) is involved in the ITU-T Study Group 20 (SG20) which is responsible for studies relating to IoT and its applications, and Smart Cities and Communities (SC&C). This includes studies relating to Big Data aspects of IoT and SC&C, e-services, and smart services for SC&C. Theofanis Raptis from CNR is leading a Work Item "*Current state of P2P crowd charging platforms and corresponding market needs*" in Question 5 (Q5) of SG20 "*Study of emerging digital technologies, terminology, and definitions*", which is tasked to capture and develop definitions, to contribute to a common terminology for IoT and SC&C, and to research solutions for interoperability across different technologies, taking into account end-user, regulatory and market needs. During his tenure as lead editor of the Work Item, Theofanis received a Fellowship from the StandICT.eu 2023 Fellowship Program, so as to reinforce his involvement in SG20 and Q5 of ITU-T. Due to the active involvement of Theofanis in MARVEL and the thematic interplay between MARVEL's WP2 and the Work Item, a strong synergy focused on Smart Cities developed between the two activities. The synergy within this parallel track of developments is demonstrated in the STandICT.eu report "*Following the Fellows - Impact Report from funded applicants to 4th call of StandICT.eu 2023 Fellowship Programme*", in which MARVEL is presented as a solid reference for European research projects related to StandICT.eu.

MARVEL and the European Standards

IN THIS SECTION, THE STANDARDS APPLIED IN MARVEL ARE DESCRIBED IN DETAIL. THE STANDARDS ARE DIVIDED INTO THIRTEEN TOPICS, DEPENDING ON WHICH STAGE OF THE PROJECT THEY HAVE BEEN USED.

# STANDARDS RELATED TO AUDIO-VISUAL DATA ACQUISITION
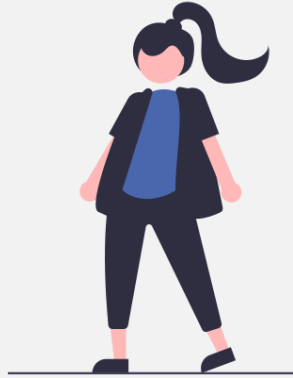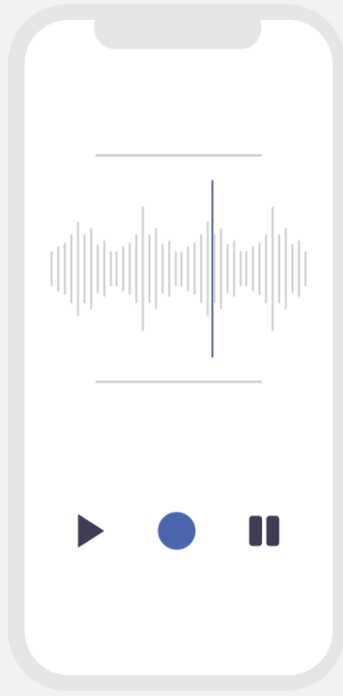
In MARVEL pilot use cases, video data is stored either in the Matroska Video (MKV) or MPEG-4 (MP4) media container formats. They both are commonly used audio-visual file formats supporting high-quality media codecs. Codecs are responsible for encoding and compressing video and audio data to reduce data amounts while maintaining perceived image quality and sound fidelity. In the Commune di Trento (MT) use cases, the audio data is encoded with the Advanced Audio Coding (AAC) codec. In the GreenRoads Limited (GRN) and Novi Sad (UNS) use cases, audio data is stored in uncompressed Pulse-Code Modulation (PCM) format. The uncompressed format is used to store audio at the highest possible quality and bitrate to enable scientific research and analysis of high-quality audio data. For storing high-quality video data, H.264 is used, providing lower bit rates than other compression standards.

Audio-visual data is streamed with Real Time Streaming Protocol (RTSP), which is an application-level network protocol for multimedia data to establish and control media sessions between endpoints. RTSP is particularly well-suited for streaming live video, as it enables real-time control over the delivery of media streams, allowing viewers to watch the video as it is being transmitted over the network. We opted for RTSP instead of other media streaming options, such as Dynamic Adaptive Streaming over HTTP (DASH), for its low-latency transmission without adapting the video quality (reflected as resolution variations), which is more desirable for further AI analytics. By using RTSP, use case partners are able to provide recordings with a high-quality, low-latency video streaming experience that can be accessed from a variety of devices and platforms in the MARVEL framework. Cameras used in the GRN use cases are equipped with Open Network Video Interface Forum (ONVIF) capabilities, which is a global open standard for the interface of physical IP-based security products. This enables easy integration of cameras with other ONVIF-compliant products, such as video management systems, access control systems, and other security devices. ONVIF compliance ensures that the cameras adhere to a set of interoperability standards, enabling them to work seamlessly with other devices from different manufacturers. The MEMs microphones used in Trento Municipality and Novi Sad pilots provide a digital output with Pulse-density modulation (PDM) format. The AudioHub board acquires the PDM signal from the different microphones (up to 8) and converts them to PCM format, as this is a more common format in audio processing. The raw PCM signal is streamed to the next node over Transmission Control Protocol (TCP).

STANDARDS RELATED TO ARTIFICIAL INTELLIGENCE

In a project such as MARVEL, where AI is used to derive intelligence and insights from audio-visual sources, it is important to pay attention to the current view and regulations at European and national levels with regard to AI. Specifically, it is crucial to understand the implication of the EU AI Act legislation proposed by the European Commission (EC) to regulate AI systems with the aim to balance between protecting the rights of individuals and enabling innovation. The AI Act proposes a categorisation of risks in AI applications from low risk to forbidden practices. MARVEL adheres to GDPR issues and pays attention to ethical and privacy aspects, the audio-visual data being anonymised by masking human faces, vehicle number plates and human speech. But nevertheless, awareness of this proposed legislation and the related standards under development is paramount.

MARVEL Standardisation White Paper
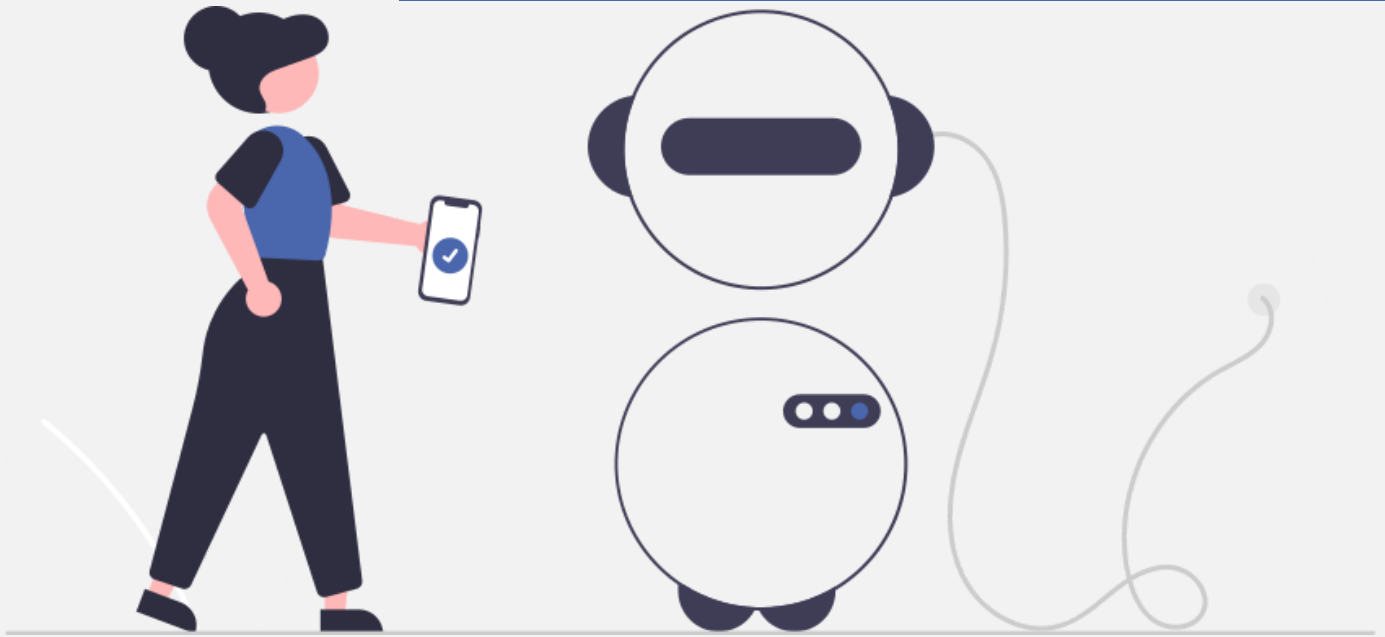
The EC in collaboration with European Standards Organisations (ESOs), such as CEN/CENELEC or ETSI, and with other international bodies such as International Organization for Standardisation (ISO) or Institute of Electrical and Electronics Engineers (IEEE), are embarking on a new legislative framework for AI development of products and services as well as the redaction of the standards that go with it. This is in line with the efforts from the EC towards the European single market. The EC published in April 2023 the last of its annual versions of its standardisation strategy[3] towards promoting the EU values and rules and the importance of standards in this process. The EU legislation will be supported using Harmonized Standards, in other words, standards developed by ESOs over formal requests issued by the EC supporting the legislation and that might be mandatory. At the end of 2022[4], the EC published its draft standardisation request related to the proposed AI Act, asking CEN/CENELEC formally to develop standards in support of the regulatory requirements set out in the AI Act. The standards will include specifications, methods, and a framework for AI products and service developers to achieve regulatory compliance. The current views of the efforts related to standards in support of the AI Act[5], and an in-depth analysis of the AI standardisation landscape in Europe[6] are available on the Joint Research Centre (JRC) site from the EC. Besides CEN-CENELEC JTC 21 AI committee, the EU is looking to other international AI standards, such as the ones developed by the ISO/IEC JTC1 SC42 AI committee, as well as the IEEE, like IEEE 7000 series of standards for building ethical systems, P7001/04, and P7003.

Currently, there are no standards related to benchmarking or assessing the performance of audio content analysis AI systems. However, there are de-facto evaluation practices popularised by the DCASE Challenge that are widely used by the research community and developers. MARVEL partner TAU, is directly involved in the DCASE challenge through the collection of datasets, development of models and proposal of evaluation metrics. The DCASE Challenge presents various environmental audio content analysis tasks annually to the community with clearly defined task definitions, open development and evaluation datasets, evaluation metrics, and the system ranking method. After the active phase of the challenge, the research community can still compare their novel AI systems to other state-of-the-art systems by following the same evaluation setup. A similar case in the image processing domain is represented by the ImageNet Large Scale Visual Recognition Challenge (ILSVRC). The ILSVRC is meant for evaluating algorithms for object detection and image classification at large scale. The idea is to allow researchers to compare progress in detection across a wider variety of objects, and, more in general, to measure the progress of computer vision for large-scale image indexing for retrieval and annotation. The most popular challenge is the one proposed in 2017 (ILSVRC'17).

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[3] https://www.europarl.europa.eu/doceo/document/A-9-2023-0136_EN.html
[4] https://ec.europa.eu/docsroom/documents/52376?locale=en
[5] https://publications.jrc.ec.europa.eu/repository/handle/JRC132833
[6] https://ai-watch.ec.europa.eu/topics/ai-standards_en

STANDARDS RELATED TO DATA MODELS

The usage of data models agreed upon by a wide community of stakeholders to enable data portability among smart cities applications is crucial to widening the exploitation of the MARVEL framework. As previously described, data models used in MARVEL are compliant with the ones proposed by the Smart Data Model (SDM) initiative. These open-licensed models have been defined jointly by FIWARE Foundation, TMForum, IUDX, and OASC.

In the MARVEL data model section was explained how the results of the AI inference models can be perceived as some kind of event, an alert, or an anomaly. MARVEL is therefore reusing and extending the SDM data models for *Alert*, *Anomaly*, and *MediaEvent* to represent the results of the inference data in MARVEL. In this way, results from many AI models are homogenised and treated as one of these three types, making them easily manageable as well as compatible with data models from other cities, such as the ones under the OASC initiative. Besides these data models, MARVEL also uses the SDM data models for Camera and MLModel for the static definition of the infrastructure (cameras or microphones) and Machine Learning models, respectively.

STANDARDS RELATED TO INFORMATION SECURITY

SECURE CONNECTION

The EdgeSec VPN component is a light virtual private network (VPN) software based on n2n (network-to-network), which makes it easy to create virtual networks bypassing intermediate firewalls. This component developed specifically to provide comprehensive VPN functionality within the context of the MARVEL E2F2C Kubernetes cluster. The EdgeSec VPN brings together all the participating nodes as if they were under the same local network making any NAT or firewall transparent to the communication between them. Essentially all participating computing devices form a full mesh network where every device has a direct connection with every other device. By establishing a VPN connection, it is possible to encrypt the traffic between different components of the cluster, making it more difficult for unauthorised users or malicious entities to intercept or eavesdrop on the data being transmitted.

EdgeSec is used in the MARVEL framework allowing Kubernetes nodes to be securely connected over the Internet, securing communications of all components of MARVEL that exchange data across the network. It uses several standard cryptographic protocols and algorithms to secure the exchanged network traffic. Supported encryption algorithms include AES, ChaCha20, and SPECK. The payload encryption that is selected for the edge nodes is AES. AES, which stands for Advanced Encryption Standard, is a widely used symmetric-key encryption algorithm that is approved by the National Institute of Standards and Technology (NIST). The rest of the supported encryption algorithms are also standardised. Chacha20 has been published as an open standard by the Internet Engineering Task Force (IETF) as RFC 8439. Finally, SPECK has been published as a standard by the National Institute of Standards and Technology (NIST) as NIST Special Publication 800-90B.

DATA CONFIDENTIALITY

EdgeSec Trusted Execution Environment (EdgeSec TEE) provides a trusted and protected environment for ensuring the confidentiality and integrity of data and code. EdgeSec TEE takes advantage of Intel Software Guard Extensions (Intel SGX) technology that is supported by Intel processors. It is used in the context of MARVEL for achieving the isolation of an execution environment for the sensitive MARVEL services. Intel SGX technology is standardised by the Trusted Computing Group (TCG), a consortium that develops open standards for trusted computing. The TCG has created a specification for SGX called the TCG SGX Architecture Specification, which defines the interfaces, protocols, and functionality of SGX technology. This specification ensures that SGX implementations from Intel vendors can work together and are compatible with each other. It also provides guidance on SGX implementation, including security considerations and best practices. The TCG aims to promote the adoption of trusted computing by standardising SGX technology and ensuring that users can trust the security and integrity of SGX-enabled platforms.

MARVDASH

MARVdash is a dashboard service for facilitating interaction with the MARVEL E2F2C cluster, by supplying the landing page for users, allowing them to launch services, design workflows, request resources, and specify other parameters related to execution through a user-friendly interface. MARVdash is designed by MARVEL partner FORTH as a toolkit, emphasising flexibility and extensibility to allow users to adapt it to their specific needs and preferences. As such, it provides a set of tools that developers can use to build custom solutions. Standards and protocols focus on defining a common set of rules and specifications for uniform behaviour across different systems which is not the case for MARVdash.

It is secured via Transport Layer Security (TLS) with certificates that are authorised by Let's Encrypt. Let's Encrypt is a free and automated certificate authority that provides digital certificates for websites to enable secure HTTPS connections. Additionally, all components deployed through MARVdash that have a web interface are proxied via the internal mechanisms of MARVdash, enabling them to be secured with Let's Encrypt as well. Let's Encrypt adheres to the standards established by the CA/Browser Forum, an industry organisation that creates criteria for the issue and maintenance of digital certificates. It is also standardised by the Internet Engineering Task Force (IETF) as RFC 8555. Moreover, the Automated Certificate Management Environment (ACME) protocol, an open standard for automating certificate issuance and renewal, is used by Let's Encrypt.

MARVEL DATA CORPUS

The MARVEL Data Corpus is one of the main outcomes of the overall project. It is a Big Data repository of open datasets for smart cities, which has been produced during the lifespan of the MARVEL project by MARVEL partners FORTH, STS, PSNC and the three pilots GRN, MT and UNS. The datasets are provided for free to scientific and industrial communities and the repository is meant to reach the 3.3PBs in size. The Corpus operation is supported by a Service Level Agreement (SLA), which covers the core elements of its internal function. Self-paced assessments are also performed to evaluate the compliance with main elements of the standard ISO/IEC 27001:2022-Information security, cybersecurity and privacy protection and ISO/IEC 29100:2011-Information technology and the General Data Protection Regulation (GDPR) for privacy. The main SLA is provided by the infrastructure provider and covers the proper availability of the main storage services. These aspects are monitored via Zabbix agents, with the availability being measured at 99.9% during trial periods. Availability is one of the building blocks of the Confidentiality, Integrity, and Availability (CIA) triage.

Thereupon, Sphynx security and privacy assurance platform[7] is deployed by MARVEL partner Sphynx Technology Solutions AG (STS) in order to continuously monitor and verify that the system is fulfilling the defined security and privacy criteria. Customised agents, as well as agents that leverage the Elasticsearch-Logstash-Kibana (ELK) technology, are collecting data in real-time concerning CIA properties and privacy. The main security controls include TLS communications for security in-transit, network fragmentation, logging, and traceability mechanisms, real-time intrusion detection and alerting technologies, as well as the core defensive elements of firewalls, proxies, anti-viruses, user authorization policies, strong password policies, etc. For privacy, the ingested data (video or audio files) are anonymized in advance before being stored in the Corpus. The datasets are publicly provided for free non-commercial use under a Creative Commons licence (CC-BY-NC), which is a simple and standardised way to grant copyright permissions. Also, the users interact with the overall infrastructure via a role-based access control policy, permitting different levels of access and privileges. Procedures for users or citizens to contact and report GDPR violation issues are also in place (i.e., via email communication).

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[7] Products - Sphynx Technology Solutions AG

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STANDARDS RELATED TO DATA PROTECTION AND PRIVACY STANDARDS

All tasks under the MARVEL project are carried out in a manner that adheres with GDPR 2016/679, the ethical requirements imposed by the Ethics Appraisal Scheme, and other relevant ethical and regulatory requirements. To ensure those requirements, anonymization and encryption algorithms for human identifiable information (voice, body, face characteristics) is deployed at the edge and for further processing, only extracted features (data processing) is sent to the cloud from which the original data cannot be recovered.

The MARVEL legal and ethics manager, in collaboration with the project coordinator and other project partners, has developed the project-specific regulatory framework, to not only meet relevant regulatory requirements, including those set forth in EU Law and European Commission regulations but also to follow the best standards from relevant industries and fields, including those focused on the development of smart cities. Thus, project partners not only adhere to relevant data protection requirements and the requirements of EC Horizon but also observe the principles for trustworthy artificial intelligence set out by the European Commission in the Guidelines for Trustworthy AI[8].

STANDARDS RELATED TO HPC INFRASTRUCTURE AND RESOURCE MANAGEMENT

In the MARVEL project, Instytut Chemii Bioorganicznej Polskiej Akademii Nauk (PSNC) provides and manages High Performance Computing (HPC) infrastructure and virtualized private cloud, which is a base for deploying software stack and storing project data in the MARVEL Data Corpus. In order to provide services with high reliability and quality for users and customers, PSNC has implemented the Integrated Information Security Management System (IISMS) compliant to standards ISO/IEC 27001:2022 and ISO 9001:2015. Certificate PN-EN ISO/IEC 27001:2017-06 obtained from independent certification body TUV NORD confirms that PSNC manages information security (including IT security, physical security, and business continuity) in line with the best global standards and practices in this field. The Certified Information Security Management System covers the areas of new-generation computer networks, distributed data processing and management, the Internet of Things, providing applications and ICT services, and cyberspace security. Certificate PN-EN ISO 9001:2015, in accordance with ISO 9001:2015, includes quality control and reliability of processes implemented at PSNC. It covers several key strategic areas of activity such as the development and implementation of software and information systems, computing and storage services, cloud services and internet platforms, collocation, and ICT consulting and security audits.

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[8] https://digital-strategy.ec.europa.eu/en/library/ethics-guidelines-trustworthy-ai

STANDARDS RELATED TO SOFTWARE DEVELOPMENT AND QUALITY

SWEBOK

SWEBOK stands for the "Software Engineering Body of Knowledge". It is a guide that outlines the necessary knowledge for software engineering professionals. Software development organisations consult the SWEBOK guide when creating their own processes and procedures for software development. SWEBOK has gained recognition as ISO Technical Report 19759, as an outline of the knowledge that professional software engineers should have. With SWEBOK the IEEE Computer Society promotes the advancement of both theory and practise for the profession of software engineering, providing a guide to the body of knowledge that has been developed over more than four decades.

Organisations can boost productivity, save development costs, and improve the quality of their software products by implementing the best practices and standards provided in the guide. SWEBOK V3[9] includes recommendations regarding software requirements, design, construction, testing, maintenance, configuration management, engineering management, engineering process, engineering models and methods, quality, engineering professional practice, and engineering economics. The SWEBOK Guide is widely recognized and used in academia and industry as a reference for software engineering education, certification, and professional development. Its objectives are:

1. Promotion of a consistent view of software engineering worldwide
2. Specification of the scope of, and clarify the place of software engineering with respect to other disciplines such as computer science, project management, computer engineering, and mathematics
3. Characterization of the contents of the software engineering discipline
4. Provision of topical access to the Software Engineering Body of Knowledge
5. Provision of a foundation for curriculum development and for individual certification and licensing material.

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[9] P. Bourque and R.E. Fairley, eds., Guide to the Software Engineering Body of Knowledge, Version 3.0, IEEE Computer Society, 2014; www.swebok.org

ISO 9001

ISO 9001 is a quality management standard developed by the International Organization for Standardization (ISO) that can help software development teams implement a Quality Management System (QMS). A QMS ensures that software products and services meet end-user requirements, comply with relevant regulations, and are delivered on schedule. It can serve as a framework to guide requirements gathering, design, development, testing, and deployment activities - which ISO can serve as guidance on. In MARVEL, a QMS that adhered to the basic ISO 9001 principles was established and employed for the needs of system integration and quality assurance. More specifically, the following actions were taken to apply the ISO 9001 standard:

- **Establish and maintain a quality management system and its associated procedures**. A clear management structure and procedures were established for system integration activities in MARVEL that included (i) the appointment of an Integration Manager, (ii) the formation and operation of an Integration Board, (iii) the establishment of regular review monitoring and meetings, (iv) the preparation and usage of templates for the organisation of information, (v) the clear and accessible documentation of essential technical information (e.g, API and data model specifications), (vi) the use of dedicated tools for the rapid deployment of software to the target infrastructure. Furthermore, a GitLab repository was established and was used for (i) code version control, (ii) version-controlled documentation of technical information, and (iii) issue tracking.
- **Ensure that end-user requirements are understood and met.** End-user requirement elicitation was the main initial stage of the project that led to the documentation of requirements in relevant reports, which in turn led to the overall system design and specification. Throughout the course of the MARVEL project, end-users participated directly in the design of the system by providing updates to requirements and by specifying the use cases in which MARVEL would be applied. End-users were also directly involved in the evaluation of the system by testing intermediate versions of the software and assessing it from an end-user perspective to determine if requirements were met. The regular updates to requirements and use cases, as well as the user feedback that emerged from testing guided the overall design and development of the system, ensuring that the final release would comply with all end-user requirements.
- **Develop and implement a system integration plan**. A well-defined and detailed integration plan was formed at the start of integration activities for the delivery of each MARVEL software release. The plan included a description of all main integration activities and presented their scheduling over time in a Gantt chart and a week-based unit of reference. The plan also included important milestones associated with the activities and specified the deadlines for reaching them. The plan was followed during the implementation and in cases of unforeseen obstacles and delays, it was revised internally, ensuring that the final deadline for delivery of the software release would be maintained.
- **Monitor and review progress.** Regular monitoring and review meetings were organised on a weekly or bi-weekly basis throughout the periods of system integration for the delivery of the MARVEL software releases. Furthermore, a dedicated GitLab Issue Tracking System (ITS) was used to document issues and monitor their progress. The ITS was also used to maintain a backlog, assign actionable items to single or multiple parties, serve as an asynchronous communication channel and point of information aggregation for resolving issues, organise and prioritise issues, appoint deadlines, and associate issues with the overall time plan and milestones. The ITS promoted accountability, transparency, and responsibility in the monitoring of technical progress.
- **Conduct testing and validation**. A test plan was formed and implemented for each software release that included (i) unit testing, (ii) partial integration testing, (iii) end-to-end integration testing, and (iv) formal validation testing at the end of each development cycle for software release delivery sign-off. Partial integration testing and end-to-end integration testing were coordinated by the Integration Manager and were carried out through regular testing sessions that were planned on a weekly or bi-weekly basis.

CAPABILITY MATURITY MODEL INTEGRATION

The Capability Maturity Model Integration (CMMI) is a widely recognized process improvement framework that enables organisations to enhance their software development and project management capabilities. At Maturity Level 2 (Managed), the model emphasises the improvement of project and process management practices, including the establishment of fundamental project management practices such as task identification, planning, monitoring and control, and also risk and issue management. At Maturity Level 3 (Defined), the focus shifts towards building a culture of continuous improvement, requiring organisations to establish a strong process infrastructure, implement process standardisation, and measure process performance. Maturity Level 3 also highlights the importance of proactive risk management, process improvement, and quantitative project management. By adhering to the CMMI model, organisations can achieve higher levels of process maturity, resulting in improved software quality, increased productivity, and reduced development costs.

In line with these principles, MARVEL development approach incorporated the use of CMMI practices for both tool development and work package and task supervision. Additionally, an internal review and tracking process was implemented, in addition to the project's review and tracking process. This involved frequent catch-up meetings to ensure that the risk management plan was continuously updated, and all ongoing tasks were progressing according to schedule. Furthermore, this process included reviewing the planned features by analysing short-term and long-term market trends and state-of-the-art technologies.

STANDARDS RELATED TO BIG DATA BENCHMARKING OF SMART CITIES

There are no standards per se related to technical benchmarking in smart cities. There are a few benchmarking tools and frameworks used in different domains that can be applied to typical scenarios in smart cities. The closest one to work in MARVEL is AIBench Scenario. It covers scenarios related to image and image classification or object detection, although the inference models used are not the same as in MARVEL. From a non-technical perspective, the Smart City Benchmark Maturity[10] Model by TMForum can be considered a standard to measure city maturity in terms of digital transformation.

STANDARDS RELATED TO FOG COMPUTING AND SMART CITIES

Idryma Technologias Kai Erevnas (short name, FORTH) is part of European Cyber Security (ECS) working group 6. The European Cyber Security initiative is a framework developed by the European Commission to strengthen cybersecurity in Europe. It aims to improve the resilience of networks and information systems, increase cybersecurity awareness and skills, and establish a common approach to cybersecurity across EU member states. The goals of ECS include:

● Definition of the cyber security EU R&I roadmap and vision.
● Establishment of the priorities for the H2020 Work Programme and the future Horizon Europe and Digital Europe Programme.
● Coordination of the cybersecurity activities across cPPPs, Pilots Projects for the Competence Center, EU Agencies, and other EU Initiatives.
● Identification of the synergies between civil defence and space for dual-use cybersecurity technologies.

Cryptography is one of the technologies that the European Cyber Security Organisation (ECSO) considers basic and disruptive regarding the development of a comprehensive cybersecurity R&I strategy in Europe. This is, at the same time, a critical technology for the security solutions that are offered by the MARVEL framework. In the Input from the ECSO to the Horizon Europe Programme – 2021-2027 document[11], released by ECS working group 6, US NIST standardisation competitions are considered good platforms to develop cryptographic expertise. The representation of European research groups and their involvement in the different standardisation processes is highly recommended.

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[10] https://www.tmforum.org/resources/technical-report/tr259-smart-city-maturity-benchmark-model-r19-0-0/
[11] https://ecs-org.eu/ecso-uploads/2022/10/5fdc4c5deb6f9.pdf

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STANDARDS RELATED TO QUALITY AND RISK MANAGEMENT

QUALITY ASSURANCE PROCESS AND RISK MANAGEMENT

The Quality Assurance Process has been followed during the entire duration of the MARVEL project. Whenever possible, processes described in the ISO 9004:2018 - Quality Management were adopted for guiding the project practices. These include a definition of leadership roles for establishing and maintaining teamwork, sharing resources with the project participants, communicating achieved successes externally and internally (ISO: Section 7), set up of process management structure towards achieving the goals of the project such as the Minimum Viable Product - MVP (ISO: Section 8), the establishment of a systematic approach to collect, analyse and review available information through web-forms and forms distributed to all partners, subversion repository (SVN), and communications, regular scientific & technical meetings, and individual work package meetings, the use of Key Performance Indicators (KPIs) and internal review processes (ISO: Section 10). Moreover, partners followed processes needed for resource management, including people engagement and competence development (ISO: Section 9).

Regarding Risk Management, the project followed processes described in ISO 31000:2018 - Risk management. These include risk identification (ISO: Section 6.4.2) by individual partners, task participants and/or work package participants, and communication to the consortium in work package meetings, and scientific and technical meetings (also using a dedicated Excel spreadsheet in the project SVN repository), risk analysis (ISO: Section 6.4.3) and evaluation (ISO: Section 6.4.4) in the scientific & technical meetings or dedicated risk assessment meetings of the Steering Committee, risk treatment (ISO: Section 6.5) and monitoring and review (ISO: Section 6.6). Moreover, recording and reporting of the risks (ISO: Section 6.7) has been done through MARVEL deliverable 8.1 (Project Handbook) which is a living document updated throughout the course of the project.

ISO 9001:2015 AND ISO/IEC 20000-1:2018

ISO 9001:2015-Quality management systems and ISO/IEC 20000-1:2018-Service management are essential certifications to maintain the quality standards for IT service management systems. ISO 9001:2015 is a quality management standard that aims to enhance business processes and customer satisfaction. This standard emphasises ensuring that products and services consistently meet customer requirements and comply with legal and regulatory obligations. On the other hand, ISO/IEC 20000-1:2018 provides a framework for IT service management system (ITSM), to deliver high-quality services that align with customer expectations and meet legal and regulatory requirements. Achieving ISO 9001:2015 and ISO/IEC 20000-1:2018 certification demonstrates an organisation's commitment to quality and the ability to consistently deliver high-quality IT services. This helps to build trust and confidence with customers, improve the organisation's reputation, and enhance its competitiveness in the market. In line with these quality standards, the timelines and resource allocation are periodically re-examined to ensure that ongoing tasks are progressing as per plan and that changing customer needs are met. Such a procedure helps to maintain high standards of customer satisfaction.

STANDARDS RELATED TO USER INTERFACE

The effective management and visualisation of data require adherence to internationally recognized best practices and standards, and MARVEL is committed to adhering to these standards. This section, covers how MARVEL adheres to internationally recognized best practices and standards related to user interface, focusing on ISO standardisation and information visualisation.

User Interface (UI) design plays a crucial role in creating intuitive, efficient, and user-friendly digital products. Various standards, principles, and guidelines have been developed to help designers create effective UIs that meet the needs of diverse users. The following is a list of standards and best practices used by MARVEL for UI design:

- **ISO 9241-110**: ISO has developed several standards related to user interface design, including ISO 9241-110, which provides guidance on the usability of interactive systems. The standard provides guidance on various aspects of user interface design, including usability, user-centred design, visual design, and accessibility. MARVEL, following the ISO 9241 standard created a user-friendly interface, which is also efficient, and effective, and that meets the needs and expectations of users.
- **The User Experience Professionals Association (UXPA)**: The UXPA is a global association for user experience professionals, and they have developed a set of guidelines for creating effective user interfaces. The UXPA's guidelines include considerations for user needs, design principles, and usability testing. The guidelines cover topics such as interaction design, visual design, and information architecture.
- **Nielsen's Ten Usability Heuristics**: The Nielsen Norman Group provides a set of heuristics for evaluating user interfaces, including principles such as visibility of system status, consistency and standards, and error prevention. By applying Nielsen's Ten Usability Heuristics, MARVEL user interface is more intuitive, user-friendly, and effective, leading to a better overall user experience.
- **The Eight Golden Rules of Interface Design**: Ben Shneiderman, a pioneer in the field of human-computer interaction, developed the Eight Golden Rules of Interface Design. These rules provide a foundation for creating user-friendly and effective interfaces that enhance the overall user experience. MARVEL has followed these rules to create a more intuitive, efficient and enjoyable to use user interface.

These standards, along with other guidelines and best practices such as Apple's Human Interface Guidelines, Material Design, and Microsoft's Fluent Design System, can help guide the design of ICT User Interfaces to create effective, user-friendly, and accessible experiences for users. By understanding and applying these principles and guidelines to a personalised User Interface design, an interface can be created that not only meets the needs and expectations of particular users but also provides a satisfying and enjoyable user experience. As technology evolves and user expectations change, staying up to date with the latest best practices and guidelines ensures that any interface remains relevant, effective, and user-friendly. Figure 2, shows a screenshot of the MARVEL user interface, where the user is able to choose the use case of their interest from the available ones. For example, when selected use case GRN4, junction traffic trajectories with its temporal representation, traffic event detection and vehicle trajectories, among other information is provided, as illustrated in figure 3.
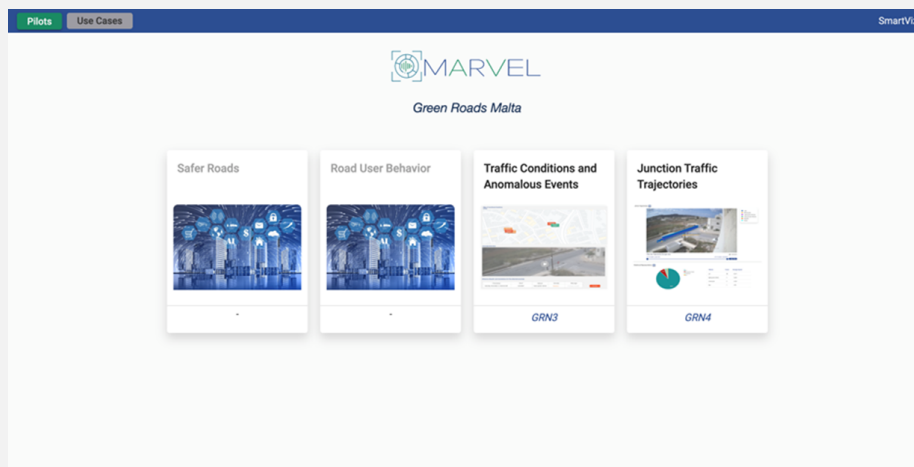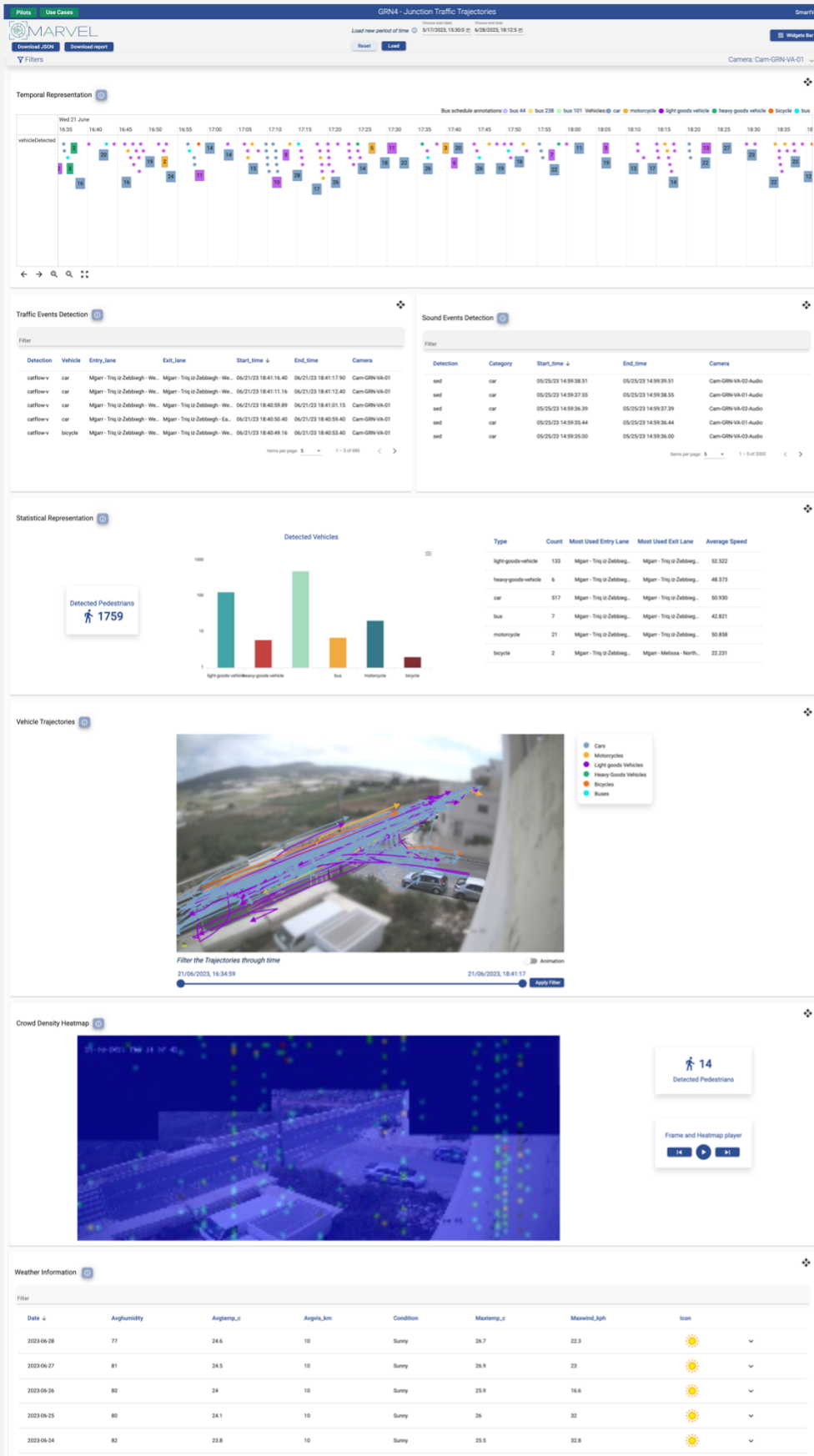

Figure 2. GRN Pilot Page

Figure 3. GRN4 Dashboard

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Standards & Guidelines related to Information visualisation

Information visualisation is the process of representing complex data and information in a visual format, such as charts, graphs, or maps, to make it easier for people to understand and interpret. MARVEL recognizes the importance of effective data visualisation in communicating complex information to stakeholders. Best practices in information visualisation are used, including adherence to principles of visual hierarchy, colour theory, and data labelling. Platforms such as Tableau and Power BI are used to create interactive and dynamic visualisations that allow users to explore data in more depth. In addition, MARVEL is committed to ensuring that all visualisations are accessible to a wide range of users, including those with visual impairments, by adhering to principles of accessibility and Web Content Accessibility Guidelines (WCAG) 2.1.

Various standards, principles, and guidelines have been developed to help designers create effective and user-friendly visualisations. The following is a list of the ones applied in MARVEL:

- **ISO/IEC 25012:2008 - Data Quality Model**: This is part of the ISO/IEC 25000 series, also known as SQuaRE (System and Software Quality Requirements and Evaluation). This international standard provides a framework for defining and evaluating data quality, including aspects related to visualisation.
- **ANSI/HFES 100-2007 - Human Factors Engineering of Computer Workstations:** This standard is developed by the Human Factors and Ergonomics Society (HFES) and the American National Standards Institute (ANSI). It provides guidelines for designing computer workstations, including visual display systems. The aim of the standard is to enhance user performance, comfort, and safety by addressing the physical, cognitive, and organisational aspects of workstation design.
- **Web Content Accessibility Guidelines (WCAG)**: These guidelines, developed by the World Wide Web Consortium (W3C), outline accessibility standards for web content, including visualisations. Following these guidelines ensures that your visualisations are accessible to people with disabilities.
- **The Gestalt Principles**: These are a set of psychological principles that describe how humans perceive visual elements and organise them into coherent patterns. These principles help guide the viewer's attention and make it easier for them to grasp the underlying patterns, relationships, and trends in the data.
- **Tufte's Principles**: Edward Tufte, a renowned expert in the field of data visualisation, has proposed several principles for effective visual communication. Some of these principles include avoiding chartjunk, maximising data-ink ratio, and using small multiples.
- **The International Business Communication Standards (IBCS)**: Set of guidelines and best practices for creating clear, consistent, and effective visualisations in business communication. The goal of IBCS is to facilitate better understanding and decision-making by standardising the way data is presented in reports, presentations, and dashboards.
- **The Data Visualisation Checklist**: Created by Stephanie Evergreen, a renowned data visualisation expert, is a practical and comprehensive guideline for creating effective and visually appealing data visualisations. The checklist addresses various aspects of the data visualisation process to ensure that the resulting visualisations are clear, engaging, and informative.
- **Color Universal Design (CUD)**: This guideline focuses on using colours effectively in visualisations to ensure they are easily distinguishable for all users, including those with colour vision deficiencies.
- **The Five Hat Racks**: The concept of the "Five Hat Racks" was originally developed by Richard Saul Wurman in his book Information Anxiety. Later he wrote the book "*Information Architect*", where he redefines the Five Hat Racks concept to form the Location, Alphabet, Time, Category, and Hierarchy (LATCH) principle. It provides a systematic approach to organising and presenting information based on the aforementioned five methods.

MARVEL has applied these standards to create visualisations that not only look good but also effectively communicate complex data and information to the audience.

ISO STANDARDISATION & INFORMATION VISUALISATION

MARVEL is committed to adhering to international standards related to information management and data quality. In this section, MARVEL practices for information visualisation are listed, which are part of ISO standards:

- **ISO 8000-1:202**-**Data quality**: provides guidance on data quality management, including principles for data quality assessment and measurement. Effective data visualisation relies on accurate and high-quality data, so adherence to ISO 8000 can improve the accuracy and quality of visualised data.
- **ISO 19005-1:2005**-**Document management**: provides guidelines for the creation, validation, and long-term preservation of electronic documents. While not specific to data visualisation, adherence to ISO 19005 can improve the accuracy and reliability of visualised data by ensuring that data is stored and maintained in a standardised and secure manner.
- **ISO 9241-210:2019**-**Ergonomics of human-system interaction**: provides guidance on the design and evaluation of user interfaces, including principles for usability and accessibility. Effective data visualisation relies on interfaces that are easy to use and understand, so adherence to ISO 9241 can improve the effectiveness and usability of visualisations.

While there is no specific ISO standard for data visualisation, ISO standards related to data quality, document management, and user interface design are used instead. The adherence to ISO standards ensures an improvement in the accuracy, consistency and usability of the visualised data.

USE CASE-SPECIFIC STANDARDS

There are ten use cases in MARVEL, divided in three pilots, municipality of Trento, municipality of Malta and university of Novi Sad. MARVEL understands that each use case requires adherence to specific standards and regulations. In the use cases taking place in the municipality of Trento (Italy), in the context of smart city monitoring and surveillance, MARVEL adheres with relevant standards related to data privacy and security. As has been stated in previous section *standards related to data protection and privacy standards*, the monitoring and surveillance carried out adheres with the GDPR 2016/679. The management of data collected by video surveillance cameras follows the regulations on the protection of privacy under GDPR. In order to comply with these constraints, artificial intelligence algorithms are used to anonymise the collected audio-visual data streams and the MARVEL partner Fondazione Bruno Kessler (FBK) is appointed as the data controller. Only anonymised data streams are shared with the project partners.

In the use cases taking place in the municipality of Malta, in the context of traffic monitoring, there are specific standards related to vehicle classification from the European automotive industry, that MARVEL adheres to in its operations. As pointed in previous section *standards related to artificial intelligence*, MARVEL adheres to the GDPR for these use cases by anonymising audio-visual data and masking vehicle number plates. For the purpose of vehicle classification, MARVEL followed the vehicle categories defined by the European Automotive Industry[12]. The classification was performed by CATFlow detector, a software asset developed by MARVEL partner GRN, where the input is a video stream and the output is a list of traffic objects tracked over the camera field of view.

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[12] https://single-market-economy.ec.europa.eu/sectors/automotive-industry/vehicle-categories_en

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Finally, in the use cases taking place in the university of Novi Sad, in the context of drone-based monitoring, MARVEL adheres to standards related to safety and airspace regulation. By adhering to these use case-specific standards, MARVEL ensures that all the operations are compliant with relevant regulations and provides high-quality services. More specifically, in terms of drone-based monitoring, standards related to safety and airspace regulations fall under the jurisdiction of the European Aviation Safety Agency (EASA).

EASA holds the responsibility of implementing, maintaining, and overseeing compliance with newly established regulations. Previously, each member state of the European Union (EU) had its own set of drone regulations at the national level. However, a recent EU regulation has been adopted, bringing equal implications to all member states. Irrespective of their mass and purpose, all drones are subject to the European regulation. This new regulation is designed to harmonise rules and foster the growth of the drone sector. The Regulation (EU) 2018/1139 on common rules in the field of civil aviation was approved by EU in July 2018[13], but also more specific regulation (EU) 2019/947 on the rules and procedures for the operation of Unmanned Aerial Vehicles (UAV) was approved in May 2019[14]. On the other hand, standards for UAV to UAV (U2U), UAV to Infrastructure (U2I) and UAV to Vehicles (U2V) communication have been recently studied, and many existing standards have been reused.

The Third Generation Partnership Project (3GPP) has completed a study to investigate the challenges and possibilities of incorporating UAVs as a new type of user equipment (UE) called aerial UE, but also new strategies are required to effectively accommodate both aerial and ground UEs in the same system. While the primary focus of 3GPP lies in connecting UAVs to cellular networks, the industry and academia are progressing in the research and development to fully utilise the potential of UAV communication, specifically by exploring the opportunity to deploy UAV-mounted flying relays and Base Stations (BSs) that can dynamically reposition themselves to enhance coverage, spectral efficiency, and user quality of experience (QoE). The widely-used IEEE 802.11 protocol can be employed by the physical and data link layers for U2U communication. It offers a solid communication range of several hundred meters with clear line of sight. Also, extensions of the IEEE 802.11, such as IEEE 802.11n, ac, ax, can provide even longer communication ranges and higher data rates. Finally, an important model is U2I communication that uses one of the existing WWAN and LPWAN protocols depending on the distance and type of service, such as 3G, 4G LTE, 5G NR, NBIoT, LTE-M, IEEE 802.16 (WiMax).

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[13] https://www.easa.europa.eu/en/document-library/regulations/regulation-eu-20181139
[14] https://www.easa.europa.eu/en/document-library/easy-access-rules/easy-access-rules-unmanned-aircraft-systems-regulations-eu

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Standards defined by Big Data Value Association (BDVA) Strategic Research and Innovation Agenda (SRIA)

MARVEL architecture follows the overall goals, main technical/not technical priorities, research and innovation roadmap proposed by Big Data Value Association (BDVA) Strategic Research and Innovation Agenda (SRIA). Figure 4 shows a mapping of MARVEL's conceptual architecture to BDV – Big Data and Analytics/Machine Learning Reference Model (BDV RA)[15].

- The *Sensing and Perception* subsystem of the MARVEL architecture maps to the "Things/Assets, Sensors and Actuators (Edge, IoT, CPS)" block of the BDV RA. This subsystem is also the main source of AV data in the MARVEL architecture, and hence it maps also to the "Media Image Audio" vertical data types block of the BDV RA.
- The *Security, Privacy, and Data Protection* subsystem maps to the horizontal block "Data protection" in the related aspects of privacy protection, anonymisation, and GDPR adherence, but also with regards to Responsible AI. Besides, this subsystem also concerns framework security at all architectural levels including secure transmissions, and as such it maps to the cross-cutting vertical concern "Cybersecurity and Trust" of the BDV RA.
- The *Data Management and Distribution Toolkit* subsystem maps to the "Data management" horizontal block of the BDV RA.
- The *Audio, Video, and Multimodal AI* subsystem maps to the "Data Analytics" horizontal block, in the aspects of ML/DL model building from large-scale datasets located at the cloud tier, and similarly for model building over data-at-rest or data-in-motion (through FedL), indicated by the pink field Training in the middle of the figure spanning edge, fog, and cloud.
- The *Optimised E2F2C Processing and Deployment* subsystem concerns deployment of AI tasks, but also model optimisation (compression, acceleration), and hence it maps to the "Data Analytics" horizontal block. Similarly for the violet E2F2C spanning field Inference, which indicates ML/DL models at runtime, making inference.
- The *E2F2C Infrastructure* of the MARVEL architecture maps to the "Data Processing Architecture" horizontal block. Specifically, the Cloud tier/HPC infrastructure of MARVEL maps to the "Cloud and High Performance Computing (HPC) horizontal block.
- The *System outputs/User interface* and the *Decision-making toolkit* subsystems map to the "Data Visualisation and User Interaction" horizontal block, where the mapping of the MARVEL Data Corpus-as-a-Service is in the sense of user interactions through various queries over data.
- Finally, the MARVEL *Data Corpus-as-a-Service* block maps also to the "Media Image Audio" vertical data types block. Moreover, it maps to and provides a specific instance of the vertical field "Data sharing platforms, Industrial/Personal" of the BDV RA.

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[15] BDVA, European Big Data Value Strategic Research and Innovation Agenda, Big Data Value Association, 2017. https://www.bdva.eu/sites/default/files/BDVA_SRIA_v4_Ed1.1.pdf

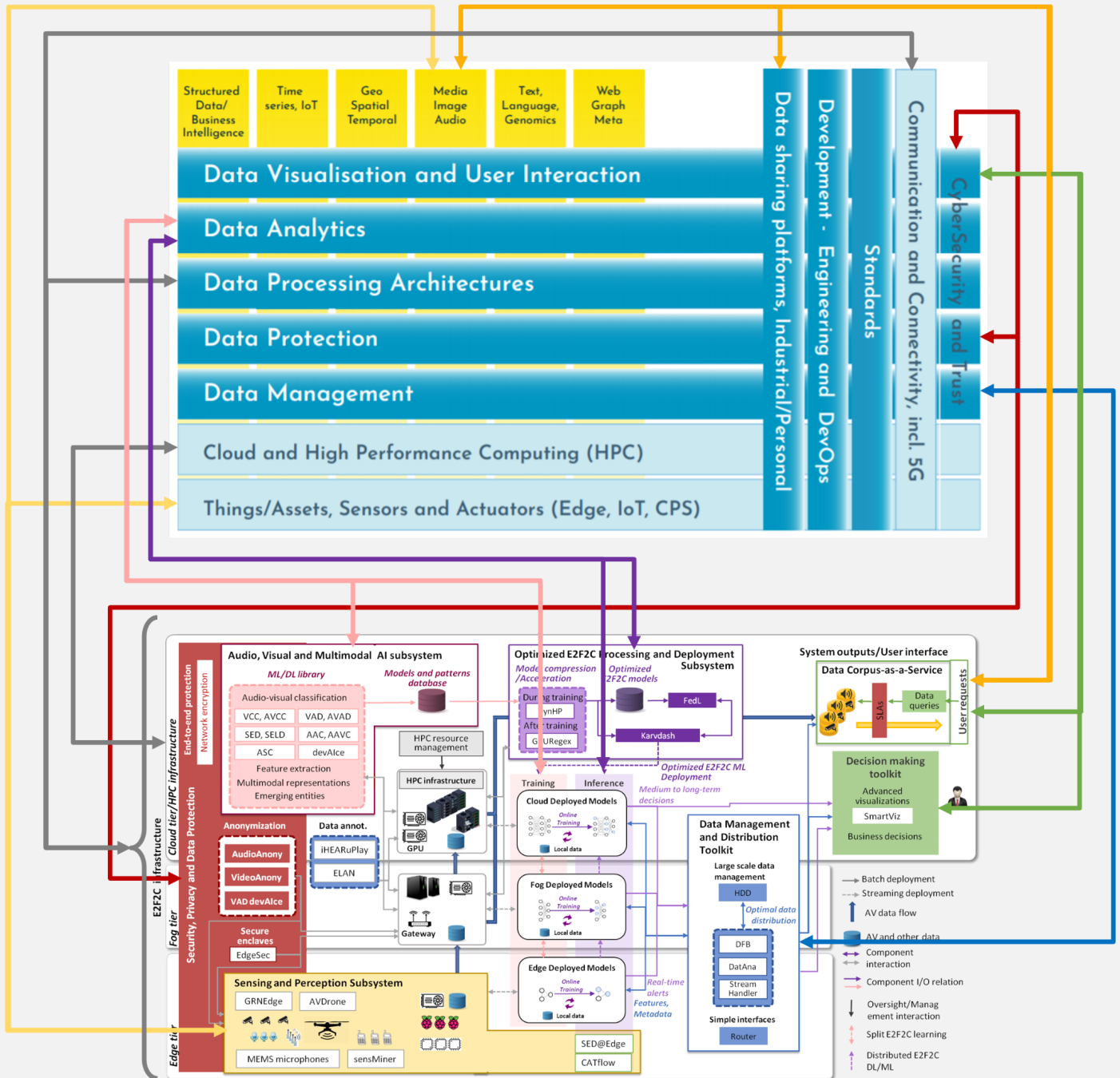MARVEL Standardisation White Paper

Figure 4. Mapping of MARVEL's conceptual architecture to BDV – Big Data and Analytics/Machine Learning Reference Model

The Data value pipeline created within the DataBench project is represented in Figure 5. The following is a list of the connections of the different subsystems from MARVEL architecture with the data value pipeline.

- First pipeline stage – "Data Acquisition /Collection" is represented in MARVEL mainly by the ***Sensing and Perception*** subsystem, for data acquisition, streaming, data extraction and in some cases also storage, depending on the type of processing and storage at the edge devices. For aspects related to data acquisition, the first pipeline stage is also represented by the MARVEL ***Data Management and Distribution Toolkit*** subsystem.
- Second pipeline stage – "Data Storage/Preparation" is also represented by the ***Data Management and Distribution Toolkit*** subsystem. With regards to data protection, this pipeline stage is represented by the MARVEL's ***Security, Privacy, and Data Protection*** subsystem, while data curation, integration, and publication are represented by the database subcomponent of MARVEL ***Data Corpus-as-a-Service***.
- Third pipeline stage – "Analytics/AI/Machine Learning" is represented by two MARVEL subsystems: (i) ***Audio, Visual and Multimodal AI*** subsystem – for ML model training; and (ii) ***Optimised E2F2C Processing and Deployment*** subsystem – for operation, model verification.
- Fourth pipeline stage – "Action/Interaction/Visualisation/Access" is represented by the final MARVEL subsystem ***Systems outputs/User interface*** and the ***Decision making toolkit***, which includes data presentation environment (both for MARVEL Data Corpus and the decision-making toolkit), and user action and interaction.
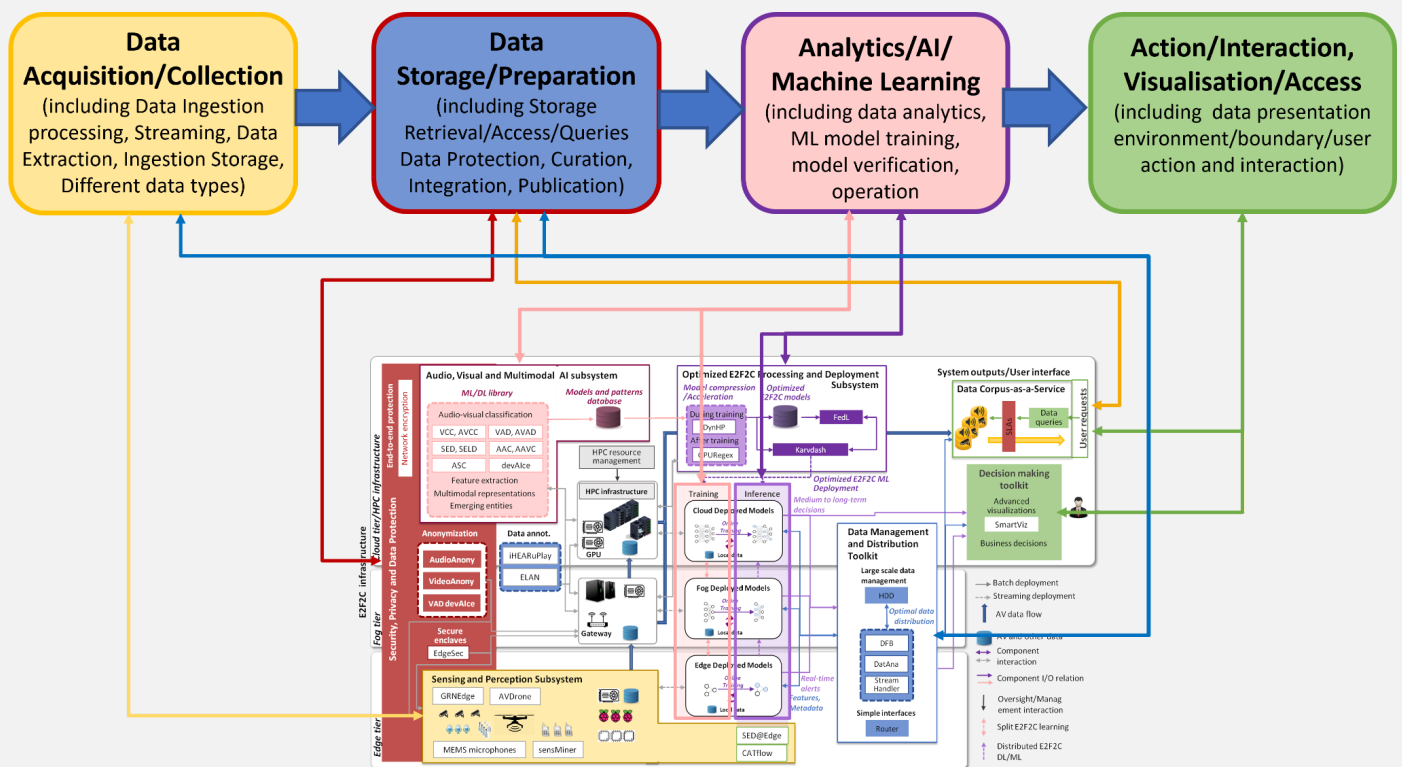

Figure 5. Mapping of MARVEL's conceptual architecture to the Data value pipeline, DataBench

Conclusions

This document presented all the standards, guidelines and benchmarks used by MARVEL in the context of smart cities. An overview of the goals and outcomes of the MARVEL project was given to provide context for the multiple standards, practices and guidelines implemented. As part of the document, crucial aspects on standardisation in the context of smart cities have been addressed, such as data protection and privacy standards, as well as information security. Scattering high-quality microphones and cameras throughout the city allows for diverse sensing purposes, enabling the acquisition of situational awareness from the surrounding environment. However, a high volume of streaming audio and visual data is not enough for citizens to gain a deeper understanding of their urban surroundings or for city managers to better comprehend their cities. A multimodal perception and intelligence for audio-visual scene recognition, event detection, and situational awareness is needed, all while respecting ethical and privacy limits. MARVEL achieved this by using novel methods, approaches and engineering paradigms in multimodal audio-visual data management and processing.

With the use of the three pilots, municipality of Trento, municipality of Malta and the university of Novi Sad, MARVEL implemented a total of ten use cases in the context of traffic behaviour and crowded areas monitoring to improve safety in cities and better ways of reacting to unexpected events. The use cases highlighted how challenging the problem of standardisation is, where the societal needs have to be ensured while the benefit of digital tools is best standardised. While there are existing standards for smart cities, there is still a need for more well defined, concrete and specific standards towards different use cases. The present document provided a list of best practices, guidelines and standards to follow, aimed to bridge the gap between citizens and standardisation.

Future recommendations towards the standardisation of smart cities should focus on aspects related to collaborative efforts, where governments, industry and academia work together to develop global standards for all kinds of cities. The continuous assessment is an important aspect to implement in future work, since technology is rapidly changing and a dynamic framework is necessary.