Building an ecosystem where IoT, edge and cloud converge towards a computing continuum

The 11 September 2020 workshop on Internet of Things and Edge Computing covered the opportunities of edge and provided insights into the requirement for orchestration with cloud services, the importance of integrating connectivity and computing with AI-based reasoning and automation. It highlighted the need for an Open Industrial Platform for Cloud-Edge Orchestration addressing the technology challenges and competitive impact for European stakeholders in light of their role in a data economy.

The workshop on IoT and Edge Computing: Future directions for Europe, organised by the Coordinated Support Action (CSA) Next-Generation Internet of Things (NGIoT) together with the Alliance for Internet of Things Innovation (AIOTI), brought together stakeholders – over 300 registered participants from industry, academia and SMEs from Europe and beyond – to share views on the emerging needs and opportunities for European Edge IoT, learn from key voices in industry and public sectors, and to identify the most promising paths forward. Within the 25 speeches and presentations, over 170 participants were able to listen to a discussion on the opportunities and challenges of IoT and Edge computing in Europe, as well as the current position of European stakeholders. The following report summarises the highlights and main themes of the workshop and reflects on future strategic orientations in the context of Horizon Europe in the thematic context of “From Cloud to Edge to IoT”.

The workshop drew attention to the future opportunities of Edge Computing, its role of safely connecting devices and providing an orchestration with cloud services, the importance of integrating connectivity and computing with artificial intelligence (AI)-based reasoning and automation. The findings of the workshop underline the importance of the topic for a European Data Strategy, highlighted needs from a sector-specific perspective, and reviewed related technology trends and major obstacles.

In line with Europe’s key policy lines for digital autonomy and the Green Deal

Strategic autonomy in key industrial sectors. The first European Foresight Report published in September 2020 highlights 5G connectivity in combination with the Internet of Things (IoT) as critical elements of an open strategic autonomy as key to developing the European digital economy. The study on Emerging

**Edge computing drives decentralisation and decarbonisation in support of the Green Deal.** Decentralisation triggers a structural and regulatory change in key sectors like smart energy, intelligent infrastructure and the ‘from farm to fork’ paradigm to achieve flexibility, agility to match demand-supply, and responsiveness. Presentations from the energy, automotive, health and farming sectors reported benefits from more and distributed intelligence and autonomy at the edge. Innovative edge solutions will translate into new business opportunities and structural change, for example, decentralised energy grids, autonomous driving, and automated food chains. Systemic changes are a key part of the Green Deal, for making sure Europe reaches the ambitious goals of reducing carbon emissions across many different sectors of our society and economy.

The energy system needs to undertake a fundamental change from a system where production is responsive to changing demands, to a system where the demand follows renewable energy production as well, in order to contribute to the electrification of the mobility sector. This systemic change calls for distributed IoT solutions and Edge computing to unlock the necessary flexibility at all levels across different sectors. At the same time, the role of the distribution system operator (DSO) has to transform from the delivery of electron to a system integrator, where consumer services are tailored to the flexibility of demand and green production.

Intelligent edge to monitor dangerous intersections. The edge technology drives intelligent infrastructure for connected and automated mobility (https://ec.europa.eu/digital-single-market/en/connected-and-automated-mobility-europe) (CAM). For an autonomous vehicle to smoothly travel through a city, it will need to have low latency infrastructure (5G connectivity and computing) that allows it to continuously “see” its surroundings around the next corner. Beyond achieving more fine-grained real-time traffic monitoring, edge intelligence will combine system of sensors (real time location services (RTLS), radar and LiDAR, etc.), video-based detection, connected traffic signals and remote monitoring capabilities, and transform roadway junctions, busy corridors and difficult roadway connectivity sections to allow roadside cognition and localisation in anticipation of hazardous events or dangerous situations.

Computing at the edge has grown steadily over the past decade, driven by the need to support computing and analytics closer to the physical world, in order to reduce latency and tackle data deluge due to billions of connected devices and systems. Edge computing lies between physical things in the real world as monitored and controlled by IoT devices (sensors and actuators), via layers of edge nodes to the data centre. The emergence of AI as a major force in IoT efforts also arrives against the backdrop of several important IoT-related trends, like cloud-based IoT services, and the dramatic increase of AI capabilities in data centres.

In addition, massive IoT data generation is pushing network capacity to its limits across industries; analysing data close to where it is generated in the physical world, rather than passing it up to a data centre, reduces network load, saves energy and costs, as well as the time lag (latency) between generating data and acting on it. Time critically is essential for optimising industrial processes, automation in connected driving, mobile health and integration of volatile energy sources into grid operations. The localisation of data and computation can improve privacy, security, reliability, resilience and safety, which, taken together, comprises trust.
The opportunity for Cloud-Edge-IoT:

With the proliferation of IoT, the need to build up critical edge is becoming urgent. By bringing responsiveness and innovation to where it is needed, intelligent IoT devices accelerate the convergence of information and operational technology, (IT and OT) and fuel the digital transformation of industries like energy, farming, automotive, or manufacturing. Intelligent endpoint devices and systems have the ability to not only connect with one another, but also to enable rapid experimentation, real-time insights, and align to deliver services on demand for better operations and increase competitive position. With the increase of the volume of data produced by IoT devices, there is a growing demand of applications capable of monitoring and analysing data flows close to their sources, not just on the cloud, or anywhere else along the IoT-to-cloud path. Where computation should occur depends on the specific needs of each application. Strict real-time constraints require computation to run as close to the data origin as possible (e.g. IoT gateway). Conversely, batch-wise tasks (e.g. Big data (https://ec.europa.eu/digital-single-market/en/big-data) analytics) are advised to run on the cloud where computing resources are abundant. OT production, sophisticated supervision like predictive maintenance, and safety control can be implemented in edge nodes. AI analytics closes the loop to cope with the tremendous amount of data generated by IoT systems and focus attention on the most relevant events. A new operating system at the edge was called for, e.g. in the automotive sector, or a smart energy operating system in the energy sector; both should support data sovereignty while keeping data local within different security boundaries as defined by the particular application. Examples are an autonomous or semi-autonomous vehicle, which requires the ability to react to sensor data “quicker than the blink of an eye” to respond to events in the roadway. On the other hand, in a factory setting, an AI-driven monitoring system has the ability to sense and respond to a production machine that needs recalibration or spotted machine fatigue before the failure. As intelligent edge devices take on critical analytics and decision-making tasks, the doors open to innovation and new ways of service delivery on the spot. Sensors and devices monitoring and managing vehicles, factories, warehouses, urban traffic, renewable energy and farms are now forming the new central nervous system of the economy.

The challenges for intelligent edge computing:

- **An operating system to enable real-time capabilities:**
  Intelligent edge computing provides for the adoption of high-level capabilities such as AI and analytics, and abstract from an underlying complexity of heterogeneous sensor and system environments. An operating system (OS) for the edge should enable the processing of data close to its sources and provide for the real-time response that is essential in many applications. AI and machine learning, in fact, demand real-time access to data and responsiveness to real-life events.
  There are different flavours to describe the paradigm shift. Edge computing functions can be an extension of the centralised cloud or it can be a new device of edge architecture where intelligent edge computing functionalities are integrated in intelligent devices, such as a smartphone, drone, video camera or connected vehicle. Intelligent edge computing provides for the adoption of high-level capabilities such as AI and analytics and abstract from the underlying complexity of heterogeneous sensor and system environments, virtualisation of computing and network resources. There is a need for new architecture concepts; automotive companies like VW have called for a modular meta-OS for the edge. In the energy domain experts called for a smart-energy OS, as a framework for enabling flexibility in energy consumption by controlling the power load in IoT-enabled systems. Some fundamentally new concepts have been presented as “guardian angels” or personal assistants, sitting at the edge of federated personal devices, seamless device and resource management across distributed edge nodes.
or a tactile internet to establish an seamless intuitive, context-driven interaction with the future internet resources.

**A paradigm shift for IoT - from monitoring to outcome-driven platforms:**
Design smart edge nodes built on European strengths in microsystems, embedded sensors and system design puts Europe in a pool position for designing the next generation of connected devices and systems. Future smart edge nodes will have more power on device-level at the edge, will support AI-based algorithms and build on new topologies for connectivity. Embedding AI computing by exploiting a new generation of AI microprocessors or AI accelerators will enable machine learning, inference on edge devices, and computing power for training purposes. Future IoT architectures will benefit from emerging technological concepts like swarm computing, stochastic modelling and control, neuromorphic computing and advances in security. New generation of collaborate IoT nodes that integrates AI and machine learning: algorithms to hardware implementation, with energy-efficient computing power and architectures to dispatch edge control and swarm intelligence. New architecture concepts for edge and sensor system integration allows us to deal with intermittent connectivity, volatile devices and resources to increase autonomy, more intelligent sensing and reducing latency. IoT leverages edge computing to reduce bandwidth costs through processing data locally to improve agility through real-time on-premise decision to allow edge devices and processes to function autonomously. These are based on concepts like the Far Edge, Deep Edge that encompass distributed computing, advances in AI chips, Distributed Ledger Technology, miniaturisation and innovative sensing concepts. Additionally, new concepts for collaborating smart node software are required, which allow dispatching edge control and swarm intelligence, and enable complex planning and control tasks between the edge and emerging mesh topologies.

**The orchestration of resources to form a computing continuum**
The orchestration of resources in a wide ecosystem where IoT, Edge and Cloud converge to form a computing continuum also known as cloud-to-things continuum. Edge computing could trigger a paradigm shift in cloud computing; it has the potential to trigger a shift from the widespread of cloud-based infrastructure models which is dominated by leading internet companies and crystallise a future strategy for European product and system innovation. In particular, typical data-intensive workloads that consist of data-analytics tasks such as machine-learning AI and descriptive analysis are perfect candidates for the cloud-to-things continuum, since data is generated typically on the edge (by IoT devices) with use of a serverless pipeline, whereas the analysis (either for model training or execution of descriptive tasks) traditionally happens on centralised locations on the cloud with use of distributed processing frameworks. Edge computing functions can be hosted on a micro-modular datacentre or micro server, where the edge server operates as an extension of the centralised cloud in the context of an overall application or workflow that is managed in the cloud, but executed at the edge. Future edge infrastructure concepts are interest driven: cloud-edge concepts target to reinforce edge visibility in the cloud (similar effort by GAFAs target edge application, the Voice Interoperability Initiative), examples include Mobile Edge Computing (cloud -5G MAC integration), Fog Computing (stressing the federation of micro cloud servers, the edge inheriting the cloud attributes and orchestration of cloud edge).

**Striving for leadership in an open industrial platform for Cloud-Edge orchestration:** Application designers would greatly benefit from a support for a flexible and dynamic provisioning of computing resources along the cloud-to-things path, that is, a provisioning system capable of orchestrating (activating, deactivating, integrating, etc.) computing resources provided by heterogeneous computing infrastructures. Furthermore, that system shall also take into account and cope with the heterogeneity of providers owning the computing infrastructures in terms of service APIs, guaranteed service levels, data management policies, etc. The key to success and innovation for many enterprises in the digital era is the platform
approach: an ongoing process of opening up applications, systems, data and services to partners, communities and other interested parties, via APIs, cloud services, modular building blocks and open architecture and standards for computing and communications. With intelligent edge devices, participants in platform networks have standardised access to data across different vendors, computing power and insights that can be leveraged and shared to strengthen the products and services involved.

The proliferation of edge applications across a growing number of market segments causes an increase in the complexity of the overall edge ecosystem. European actors have a clear opportunity to establish market and services where GAFA and China have started to explore maturing markets: moving beyond a simple send-data-to-the-cloud, lacking automation service level whilst preserving privacy, security and solving societal challenges like energy consumption, decentralisation and decarbonisation, develop modular building blocks and open architecture and standards for computing and communications.

• **Open up experimentation and innovation for SMEs:**

Edge Computing is an emerging domain building a glue between today’s control and automation systems and the cloud, supported by an emerging new ecosystem. Participants stressed the fact of on emerging ecosystems for Edge Computing, around intelligence sensing (e.g. sophisticated vision like MobileEye) and embedded AI technologies, tactile internet and 5G connectivity, IoT and new business models and start-ups (e.g. exploit X as service models, foster an app economy). For many organisations, the ability to act on innovation was limited by access to available data and computing resources. Intelligent end devices and open standards-based architectures make it possible to connect to and normalise formerly silo-ed information across systems of different vendors or across sectoral boundaries. Especially for midcaps and SMEs, it is essential to adopt innovation on processes and new innovative services. SMEs could benefit from intelligent processing capabilities distributed across various endpoints and transform their business models, but would require experimentation and training on emerging edge technologies and standards, which can take place close to the source of data, as well as in closer proximity to where automated processes and decision-making are introduced at the edge.

• **A Single Market and trustworthy infrastructure for Edge Computing:** Europe needs a trustworthy infrastructure that builds on a flexible federation and good business offer to manage the vast amount of IoT-generated data. The EU needs to identify the catalysts that may speed up innovation at the edge, scale up and invest in infrastructure, orchestrate across relevant players of the value chain and facilitate coordination on horizontal issues (e.g. interoperability and open standards to avoid fragmentation of edge infrastructure), synergies with open source software framework and hardware, governance and coordination at EU level (e.g. a forum), as well as an open level playing field for newcomers and start-ups and opportunities Europe needs to avoid vertical or geographical islands of implementation. Europe needs a single market for IoT and edge systems, founded on open standards, able to connect seamlessly and on a plug-and-play basis to the edge and the cloud; a thriving edge ecosystem for real-time system integration, where open platforms are used across vertical silos to help developer communities to innovate.

**Conclusions**

Computing capabilities at the edge have grown steadily over the past decade, driven by the need to support computing and analytics closer to the physical world in order to reduce latency and tackle data deluge due to billions of connected devices and systems. The dramatic increase of AI algorithms and computing capabilities as a major force in IoT efforts is simultaneous with several important IoT-related trends, like energy-efficient computing and distributed architectures, to dispatch edge control and swarm intelligence.
The workshop drew attention to future opportunities of Edge Computing including its role of safely connecting devices, and provided insights into the requirement for orchestration with cloud services, the importance of integrating connectivity and computing with AI-based reasoning and automation. It highlighted the need for an Open Industrial Platform for Cloud-Edge Orchestration addressing the technology challenges and competitive impact for European stakeholders in light of their role in a data economy.

References

2. CSA Next-Generation IoT (NGIoT (http://www.ngiot.eu/))

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