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PLANET 4

Practical Learning of Artificial Intelligence on the Edge for indusTry 4.0

PLANET4 TAXONOMY – TERMS DEFINITION

Statement of originality

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INDUSTRY 4.0 PROBLEMS AND NEEDS

1. **Process Optimization**: It is related to the macro need to improve production processes' efficiency to reduce production costs. In general, industrial processes can be optimized by improving the efficiency of equipment, workforce and supply chain.

   1.1. **Equipment and Process efficiency improvement**: Concerns activities related to the manufacturing ecosystem connectivity for alerting, running data analytics processes, and all the maintenance processes that ensure continuous readiness and operation of the industrial equipment without unplanned disruptions. It also involves initiatives for a) production planning and scheduling, b) employing industrial units that work independently without human intervention, c) legacy systems modernization and retrofitting, and d) commissioning processes.

      1.1.1. *Real-time Production and Process monitoring, analysis, and supervision*: Enables manufacturers to connect individual machines, production lines, and entire factories to a data processing system able to alert, run data analytics processes, conceive fault tolerance systems, and monitor the precision of machines.

      1.1.2. *Predictive Maintenance*: A maintenance strategy that helps industries to reduce maintenance costs and the probability of production downtime by monitoring assets' condition during normal operation and predicting when assets' next failure is likely to occur. At the core of predictive maintenance are also anomaly detection techniques that aim to find anomalies in an industrial facility early and alert the manufacturing supervisor to perform maintenance tasks before the issue becomes severe and downtime occurs.

      1.1.3. *Production Planning and Scheduling*: Enables industries to optimize production by shortening processing time (e.g., generating the optimal sequence of operations needed to manufacture a workpiece, minimizing transportation time) and efficiently allocating equipment and human resources. Also, it concerns all those techniques that help managers to make informed decisions about repairing or replacing failed industrial equipment, hiring, and scheduling maintenance (e.g., measuring metrics maintenance time).

      1.1.4. *Fully automated production facilities*: The use of production units that can work independently without human intervention and in which a human is only a supervisor. An example of such a unit can be an autonomous machining station consisting of a general-purpose CNC machine tool, a buffer for work items and a robot whose task is to change tools and transport work items. All these devices work fully automatically and are controlled by a computer.

1.1.5. *Legacy Systems Modernization and Retrofitting*: The process of transforming older production systems to adapt them to the requirements of automated manufacturing and the industrial internet of things. An example is equipping old devices (e.g., manually operated machinery) with sensors and actuators, thanks to which we can collect data from the production process (digitization of the production process) and control the operation of these devices.

1.1.6. *Commissioning Process*: The process of ensuring that all components of the production system are correctly designed, constructed and installed, as well as that they function following operational requirements.

1.2. **Worker safety improvement and accident prevention**: Problems in this area are related to the use of effective means for workers' personal and collective protection.

1.2.1. *Smart PPE*: Wearable pieces of connected personal protection equipment that aid communication in loud or low-visibility environments, provide high visibility, respond to body and external temperatures to keep the wearer safe and alert supervisors if workers are in trouble.

1.2.2. *Worker attention and mental state monitoring*: The use of appropriate devices that monitor the employee's behaviour and performance. Representative examples are microsleep detectors, which monitor the brainwaves of an employee, and alert in case of falling asleep, as well as eye-tracking technologies (tracking the movement of the employees' eyes) to identify factors distracting them (e.g. noise, specific working hours). This category also includes the industrial need to improve workers' efficiency (e.g., elimination of wasteful motion) through analysing the industrial tasks' ergonomics and the workers' movement.

1.2.3. *People counting, analysis and crowd detection*: The use of appropriate systems that monitor the location of employees. These systems can support the navigation of employees inside the plant (indicating the optimal route to the destination), monitor designated zones where the employee should not be present for safety reasons, and count employees, which may be helpful in emergencies (e.g., emergency evacuation). Furthermore, it concerns systems which measure "closeness," "density," and "crowd size" in real-time to prevent the spread of infectious diseases such as COVID-19.

1.2.4. *Remote operation*: The equipment of the factory or manufacturing operations with the tools necessary to remotely control assets to limit employees' physical exposure in crowded spaces, harsh environmental conditions such as harmful dust, collisions, cuts, crushing, and other injuries from heavy and light industrial equipment, electrical hazards, etc.

1.3. **Supply Chain**: Needs that ensure a smooth flow of information and materials inside the company between individual production departments (internal suppliers and customers) and between the company and its external suppliers and customers.

1.3.1. *Vertical integration*: Refers to the integration of business processes in an enterprise (integration of material and information flow). As a result, elements of the production system and departments of the enterprise that previously functioned as independent can now cooperate better with each other.

1.3.2. *Horizontal integration*: Connects business partners and customers to optimize the supply chain. This interconnection enables transparency and flexibility to respond more rapidly to problems and faults.

1.3.3. *Production on demand*: (Also known as Manufacturing on Demand (MoD), Cloud Manufacturing or Demand-driven Manufacturing (DdM)) It refers to the strategy of manufacturing a product only when the customer places an order, reducing overall resource wastage.

1.3.4. *Smart warehouse and Inventory Management*: A systematic approach to sourcing, storing, selling (e.g., preparation of orders), replenishing, and tracking inventory, such as raw materials (components), maintenance materials (e.g., spare parts, lubricants), and finished goods (products). In addition, today's industrial warehouses need the highest level of product security (e.g., information leaks, false labelling, inadequate food hygiene management, malicious acts by staff or acts of corporate terrorism)

1.3.5. *Intralogistics 4.0 - material flow control*: The organization, control, and optimization of material flow within a company. Intralogistics aims to implement technical solutions, including industrial trucks and - to an increasing extent - computer systems for the intelligent transport of goods within a logistics node. These solutions allow, among others, to locate and monitor transport equipment (containers, pallets, vehicles), control the capacity of transport routes on the premises of the plant, improve the picking of goods thanks to trolleys that automatically follow the operator and adapt to his work rhythm, as well as to monitor the flow of materials and semi-finished products in the production process.

1.3.6. *Supply chain transparency and reliability improvement*: Using the right technologies to track goods along the supply chain makes predicting delivery times easier. Through these technologies, it is also possible to alert the customer about potential deliverables' damages or to control the environmental conditions (e.g., temperature, humidity) in which the goods are transported.

1.3.7. *Production Volume and Demand Forecasting*: Using historical trends in production output against customer demand to make better decisions about the quantity of raw

material to be ordered and whether new supply chains are needed or a reduction in the number of suppliers. In addition, such functionalities aim to predict how many end items and derived subassemblies must produce in specific periods to meet the forecasted sales.

1.4. **Mass Customization**: Individualization of the production process while remaining profitable for the enterprise. That is to implement technologies allowing for unlimited adaptation of products to individual customer requirements without affecting the unit production costs.

1.5. **Quality Assurance**: It is connected with the necessity to monitor the operation of machines and process parameters to identify quality disturbances and take immediate corrective and preventive actions.

1.6. **Sustainable industrial environment**: Is related to the appropriate management of industrial processes purposing of reducing energy consumption and minimizing/utilizing wastes, among others, from an environmental, economic and social perspective.

1.7. **Employee training and Assistance in worker's tasks**: The use of appropriate technologies that help prepare employees to perform a new job and support them in implementing current jobs (e.g., product design, manual assembly, inspection activities, maintenance tasks, and order picking), minimizing the risk of human errors.

1.8. **Knowledge management**: The manufacturing companies' needs on the acquisition, organization, and automatic retrieval of information from different content resources, such as technical documentation, videos, images, schematics, audio, web pages and much more, in the different phases of the industrial process.

2. **Product Innovation**: It is related to companies who need to build a new generation of products that are typically IoT connected, thus migrating the business toward a service-based solution. Product Innovation actions also aim to improve products' usability by making them easier to use and understand (User Experience redesign).

2.1. **Product servitization**: The innovation of the organization's capabilities and processes to better create mutual value through a shift from selling products to selling Product-Service Systems capable of fulfilling a more comprehensive range of customer needs.

2.2. **Usability improvement**: The need for solutions to user problems (e.g., the design of better user interfaces) that make it easier for the user to complete a task with effectiveness, efficiency and satisfaction by using the manufactured product.

2.3. **Smart products**: Disruptive initiatives aimed at building a new generation of products that completely change the usage and the associated business model.

2.4. **Cost and number of parts or component reduction**: It aims at optimizing the BOM (Bill of Material) of products, thus reducing product and production management costs.

2.5. **After-Sales Service**: The improvement of all those services that link the customer to the production company after selling the product (e.g., complaint management, warranty, field technical assistance responsible for installation, check-ups, out-of-warranty repairs and product disposal, usage monitoring, user analytics and profiling, automatic consumables reorder, etc.).

4.0 ENABLING TECHNOLOGIES

1. **Big Data**: It refers to enormous data sets that are complicated for typical data-processing application software to handle.
   - 1.1. **Big Data Frameworks**: Toolsets that provide cost-effective solutions to the challenges of Big Data processing, such as extracting insights, incorporating metadata, and assisting in business decision-making.
   - 1.2. **Data Sources/Ingestion**: The process of transferring data from multiple sources to data storage, where it can be accessed, used, and analyzed.
     - 1.2.1. *Streaming and Messaging*: Big data technique that focuses on the real-time analysis of continuous data streams.
     - 1.2.2. *Orchestration and Pipelines*: The automation of end-to-end data pipelines, from data extraction to data loading
     - 1.2.3. *Query/Data Flow*: Software that sits on top of a database or server and runs queries against that data or server's data to offer answers to users or applications.
   - 1.3. **Data Storage**: Methods and technologies for capturing and retaining data.
     - 1.3.1. *Databases*: An organized set of structured data which kept electronically in a computer system. A database management system is usually in charge of a database (DBMS).
     - 1.3.2. *Data Warehouses*: A digital storage system for connecting and harmonizing massive amounts of data from various sources. Its goal is to feed business intelligence (BI), reporting, and analytics and fulfil regulatory needs so that businesses may turn data into insight and make intelligent, data-driven decisions.
   - 1.4. **Data Analytics**: This allows businesses to examine all of their data (real-time, historical, unstructured, structured, qualitative) to find patterns and develop insights that can guide and automate decisions in some circumstances.
     - 1.4.1. *Unified Data Analytics Engines*: Multi-language engines that can be used to perform data engineering, data science, and machine learning tasks on a single node or cluster.
     - 1.4.2. *Unified stream-processing and batch-processing frameworks*: A computing framework for querying continuous data streams and performing tasks such as real-time analytics, complex event processing, and streaming analytics in a short timeframe.
     - 1.4.3. *Business Intelligence (BI) Tools*: Software utilized to create significant enterprise insights, make reports intelligently and simplify the business decision-making processes.

1.4.4. *Data Visualization Tools and Platforms*: Tools that offer an intuitive way to recognize trends, outliers, and patterns in data through graphical representation of information and data

1.4.5. *Logging & Monitoring*: A software solution that collects, sorts, and stores log data and event logs from different sources in a single central location.

1.4.6. *Spreadsheet Applications*: Applications for calculating, organizing, analyzing and storing tabular data.

1.4.7. *Data Mining*: Tools for inspecting, cleaning, transforming, and modelling information to find meaningful information, and proposing conclusions.

1.4.8. *Process Mining*: A mixture of data mining and process management approaches that analyze event data using advanced algorithms, machine learning, and statistical methodologies to throw light on business operations such as bottlenecks, capacity constraints, etc.

2. **AI**: Methods for building computerized systems that can reason, learn, and act intelligently.

2.1. **Machine learning**: A subset of artificial intelligence and computer science that focuses on identifying significant insights through algorithms trained to learn from historical data, identify patterns, make classifications-predictions, and make logical decisions with little to no human intervention.

2.1.1. *Supervised Learning*: The machine learning task of identifying a function that maps an input to an output using training data (i.e., input-output pairs).

2.1.2. *Unsupervised Learning*: ML algorithms for analyzing and clustering unlabeled datasets by discovering underlying patterns or data groupings. They are used for exploratory data analysis, cross-selling strategies, consumer segmentation, image recognition, and other applications.

2.1.3. *Deep Learning*: A branch of machine learning in which a neural network with three or more layers attempts to replicate the behavior of the human brain, allowing it to "learn" from enormous amounts of data.

2.1.4. *Transfer Learning*: The application of a previously learned model to a new problem. In transfer learning, a machine uses prior knowledge to improve generalization about another.

2.1.5. *Reinforcement Learning*: A training method that rewards desired behaviors while penalizing undesirable ones. A reinforcement learning agent, in general, can detect and comprehend its surroundings, act, and learn via trial and error.

2.1.6. *Deep Reinforcement Learning*: The machine learning discipline that blends reinforcement learning (RL) with deep learning.

2.1.7. *Semi-supervised Learning*: Semi-supervised learning is an ML approach that combines a small quantity of labelled data with a large amount of unlabeled data during training. It falls in between unsupervised and supervised learning.

2.1.8. *Federated Learning*: A machine learning approach in which a machine learning algorithm is trained across several decentralized edge devices or servers containing local data samples (usually not complete datasets).

2.2. **Computer Vision**: A branch of artificial intelligence that allows computers and systems to extract useful information from digital images, videos, and other visual inputs.

2.3. **Natural Language Processing, Natural Language Generation**: A subfield of AI that aids computers in understanding, interpreting, and manipulating human language. Sentiment analysis, topic detection, language detection, key phrase extraction, and document categorization are all tasks that it is utilized for.

2.4. **Intelligent Agents and Multiagent Systems**: A system comprising of multiple intelligent agents interacting with each other. An intelligent agent is an autonomous entity (software, person, etc.) that monitors its environment and acts under objectives.

2.5. **Soft Computing**: A set of methodologies designed to achieve robustness and low-cost solutions by exploiting their tolerance for imprecision, uncertainty, and partial truth.

2.5.1. *Fuzzy Set Theory*: It performs numerical computations using linguistic labels defined by membership functions, and it provides a systematic calculus to cope with ambiguous information linguistically. In addition, a collection of fuzzy if-then rules is a critical component of a fuzzy system that may accurately model human expertise in a given application.

2.5.2. *Neurocomputing*: Methods for simulating intelligent behavior by modelling the human brain as a continuous-time non-linear dynamic system in a connectionist architecture. Such an architecture consists of weights between a massive set of interconnected neurons (or processing units).

2.5.3. *Optimization Techniques*: Techniques that are performed iteratively by comparing different solutions until an optimum or satisfying solution that maximizes or minimizes an objective function is identified.

2.5.4. *Probabilistic Reasoning (PR)*: A way of representing knowledge in which the concept of probability is used to show knowledge uncertainty.

3. **Cloud Computing**: The offering of computing services over the Internet ("the cloud"), including servers, storage, databases, networking, software, analytics, and intelligence, to provide rapid innovation, more flexible resources, and economies of scale.

3.1. **Infrastructure as a Service (IaaS)**: A pay-as-you-go cloud computing service that provides necessary computation, storage, and networking capabilities on demand.

3.1.1. *Cloud Data Storage & Computing*: Highly scalable data storage and computing infrastructure that can be rapidly provisioned and de-provisioned on-demand.

3.2. **Platform as a Service (PaaS)**: A cloud computing approach in which cloud vendors give users a platform for app development.

3.2.1. *Device Management*: Refers to the registering, monitoring, and updating of nodes in large-scale distributed environments.

3.2.2. *Operating System*: A form of an operating system that controls the operation, execution, and procedures of virtual machines, virtual servers, virtual infrastructure, and the back-end hardware and software resources in cloud computing and virtualization environments.

3.3. **Software as a Service (SaaS)**: It enables users to connect to cloud-based programs and use them over the Internet.

3.3.1. *Media streaming software platform*: Allows audio or video material streamed over the Internet.

3.3.2. *Website Building*: A cloud-based development platform that helps in building websites.

3.3.3. *IoT Analytics Software*: It enables industries to examine and interpret sensor data from connected devices through the internet.

3.4. **Infrastructure as Code (IaC)**: A software-based IT practice that codifies and manages underlying IT infrastructure.

3.4.1. *Provisioning tools*: Tools for building, managing, updating, and deleting infrastructure resources like virtual machines, containers, networking, etc.

3.5. **Container Technology (Container as a Service)**: Virtualization of running environments to run agnostic-architecture applications and services in isolated user spaces.

3.5.1. *Containerization Platform*: Tool for OS-based virtualization, which creates multiple virtual units in the user space, known as Containers encapsulating an application as a single executable package of software that contains all of the necessary configuration files, libraries, and dependencies for it to run.

3.5.2. *Container orchestration*: This allows you to create application services that span numerous containers, schedule containers across a cluster, scale them and monitor their health over time.

3.6. **Serverless programming**: Programming paradigm where the developers are abstracted from the underlying infrastructure.

3.7. **Edge computing**: Computation approach that limits the amount of data to be transferred within a distributed system by concentrating the maximum number of computation tasks close to where data were generated (i.e., in the edge nodes).

3.8. **Fog Computing**: Computation approach that takes advantage of the individual computing capabilities of each of the nodes within a distributed system and spans the computing tasks over them.

4. **IoT and IoE**: IoT is an interconnection of various smart devices that interact with each other and with the external environment via the internet. In contrast, Internet of Everything (IoE) extends IoT and emphasizes machine-to-machine communication and describes a more complex system that includes people and their processes.

4.1. **IIoT (Industrial IoT)**: The capacity to apply the Internet of Things technology to the industry environment, connecting online objects, machines, printers and other tools inside a factory.

4.1.1. *Industrial communication protocols*: Real-time communications protocols, developed to interconnect the various systems, interfaces, and equipment that comprise a manufacturing system.

4.1.2. *Industrial Gateways and Data Acquisition Devices*: The link between the manufacturing system and the cloud which is usually the initial system-level device in the IIoT communication chain.

4.1.3. *Software Data Adapters*: It is an additional IEC61131-3 function block that is run straight as part of the control code on the PLC. During the operation of the industrial system, it reads PLC data and sends it to the superordinate intranet using an IIoT protocol.

4.2. **Physical Devices and Controllers**: Hardware-based physical objects with sensing and communication capabilities.

4.2.1. *Embedded Computing*: A computer with limited and dedicated resources to control the physical operations of a machine.

4.2.2. *Sensors (hardware)*: Devices capable of providing raw data for various process parameters with high precision and accuracy.

4.3. **Signal Processing**: A field dealing with manipulating and analysing analog and digital (sampled and quantized) signals.

4.4. **Connectivity**: Methods by which you interconnect your data processing module to devices and sensors.

4.4.1. *Radio Communication Technologies*: The use of radio waves for signaling and communication.

4.4.2. *Optical Communication Technologies*: Optical fiber transmission of data. The original electronic signals are converted into light pulses using laser or light-emitting diode light sources.

4.4.3. *IoT Messaging Protocols*: Protocols for transmitting device telemetry (or messages) from IoT devices to an IoT Messaging Hub (or Broker).

4.4.4. *Application Programming Interfaces and Programming Tools*: A software interface that allows two applications to communicate with one another.

4.5. **IoE (Internet of Everything)**: A notion that expands on the Internet of Things' (IoT) emphasis on machine-to-machine (M2M) communications to define a more extensive system that includes people and processes.

5. **Digital Twins**: The virtualization of a physical object or process to analyze and simulate the industry process.

5.1. **CAD software**: Software that facilitates the development, modification, and optimization of the design process by allowing users to build designs in either 2D or 3D to visualize construction.

5.2. **Finite Element Analysis (FEA) software**: A computational method for forecasting how a product will react to forces, vibrations, heat, fluid flow, and other physical effects in the actual world.

5.3. **Simulation software**: This allows engineers to evaluate, optimize, and compare product or system designs by modeling real-life events in a computer-generated environment.

5.4. **DTs management and orchestration framework**: A system for interacting with and managing the status of digital twins by creating a link between physical IoT devices and their digital twins.

5.5. **Digital twin data modelling**: It uses the object-oriented paradigm to store engineering information and enables modelling of physical and logical plant components as data objects encapsulating various characteristics.

5.6. **Virtual Process Controllers (VPC)**: It is the framework that receives input values from industrial cyber-physical systems, runs one or more Virtual Process Control Functions (VPFs), handles the transfer of output values to them, and can be compared to a virtualized PLC.

6. **Industrial Robotics**: Robots and machines used in manufacturing companies to automate an industry process.

6.1. **(Offline) Programming and Simulation**: Simulation and offline programming allow you to explore numerous situations of a robot work cell before setting it up. In addition,

offline programming can be used to program robots outside the manufacturing environment, thus, avoiding production downtime.

6.2. **Middleware**: A set of software tools for managing the complexity and heterogeneity of distributed systems. It's a software layer that sits atop the operating system but below the application program and provides a standard programming paradigm for distributed systems.

7. **Augmented Reality (AR) and Virtual Reality (VR)**: Technologies that work with the simulation and augmentation of the real environment.
   7.1. **VR**: A completely immersive experience that replaces a real-life environment with a simulated one.
      7.1.1. *VR glasses*: A headset with a display screen, stereo sound, sensors, and appropriate controls that provides a 3D immersive and interactive audiovisual experience.
   7.2. **AR**: Augments your surroundings by adding digital elements to a live view, often using a smartphone's camera.
      7.2.1. *AR glasses*: Wearable computer-capable glasses that overlay computer-generated information (usually 3D visuals and information such as animations and films) on the user's real-world sceneries to provide extra information.
      7.2.2. *AR Software Development Kits*: This allows developers to create digital things that merge into the real world, offering features like 3D object tracking, image recognition, visual SLAM (simultaneous localization and mapping), multi-tracking, etc.
   7.3. **AR and VR Software development, Platforms and Technologies**: Tools for creating innovative AR & VR content

8. **Additive manufacturing**: The technique of constructing an object one layer - by - layer.
   8.1. **3D Printers**: A computer-aided manufacturing (CAM) device that produces three-dimensional objects.
   8.2. **3D Printing Technologies**: Manufacturing technologies which differ in terms of material selection, surface polish, durability, as well as manufacturing speed and cost.

9. **Cybersecurity Technologies**: The use of technologies to defend against cyber-attacks on systems, networks, programs, devices, and data.
   9.1. **Security Virtualization**: Software-based security solutions designed to operate in a virtualized IT environment.

9.1.1. *Virtual Machine Monitor (VMM)*: It is a software program that enables the management, governance, and development of VM (Virtual Machines) and the functioning of the virtualized environment.

9.2. **Data Protection**: The process of protecting crucial data from corruption, compromise, or loss.

9.2.1. *Secure Communication Protocols*: Protocols for communication that ensure confidentiality, authentication, and content integrity.

9.2.2. *Key Management System (KMS)*: It relates to the administration of cryptographic keys in a cryptosystem comprising key production, exchange, storage, use, crypto-shredding (destruction), and replacement, the design of cryptography protocols, key servers, user procedures, and other relevant protocols.

9.2.3. *Public Key Infrastructure (PKI)*: It manages the issuing of digital certificates to secure end-to-end communications and protect sensitive data.

9.2.4. *Encryption*: The technique of mathematically encoding information (i.e., hiding its true meaning) so that it can only be read or decrypted by those who have the right key or cipher.

9.2.5. *Tokenization*: Tokenization is replacing sensitive data with a non-sensitive substitute known as a token, a randomized data string with no essential or exploitable value or meaning. Therefore, it does not give any method to interpret the token and reveal the original data.

9.2.6. *Blockchain*: Blockchain is described as a decentralized data ledger that is securely shared and allows a chosen set of individuals to share data. Transactional data from numerous sources may be easily collected, integrated, and shared via blockchain cloud services. Data is divided into shared blocks linked together using cryptographic hashes as unique IDs.

9.3. **Identity and Access Management**: It handles digital identities and user access to data, systems, and resources inside an enterprise to decrease identity-related access risks.

9.3.1. *Protocols*: Protocols for communication or cryptographic protocols that are specially developed for the exchange of authentication data between two entities.

9.3.2. *User Management*: It describes the collection of administrative functions that include user administration, password management, role/group management, user/group provisioning, and identity creation, propagation, and maintenance of user identity and rights.

9.3.3. *Authentication*: The phase at which the Identity Provider confirms that the user matches the identity.

9.3.4. *Authorization*: The point at which the user is granted appropriate Service Provider access.

9.4. **Security Operations**: Functions inside an organization that continually monitor and enhance the company's security posture while preventing, detecting, analyzing, and responding to cybersecurity issues.

9.4.1. *Change Management*: It includes requesting, approving, verifying, and recording system modifications.

9.4.2. *Threat Detection and Analysis*: It analyzes the whole security ecosystem to detect any malicious behavior that might compromise the network. If a threat is found, mitigating actions are taken to neutralize it before it can exploit any existing vulnerabilities effectively.

9.5. **Foundational Security**: The basic controls that ensure the security of an organization's information systems.

9.5.1. *Network*: The basic controls that ensure the security of the network.

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