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Experiential Networked Intelligence (ENI); Study on AI Agents based Next-generation Network Slicing

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Foreword

This Group Report (GR) has been produced by ETSI Industry Specification Group (ISG) Experiential Networked Intelligence (ENI).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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1 Scope

The present document analyses and studies potential ENI activities on 6G native AI capabilities. ENI has a strong focus on providing cognitive capabilities to improve the user experience of the operator. The present document covers the areas and needs for new technical projects using 6G native AI capabilities. This covers: definition of the use cases and requirements of Core Network (CN) Large Language Models (LLMs), definition of the CN-Agent to facilitate interaction between the CN and the CN LLMs, identification of the key functional modules and interfaces of the CN-Agent, and the key technologies required. Network slicing is used throughout the present document to explain the operation of this system. However, this is not a limiting case, and the system described in the present document is intended to serve a large variety of CN use cases.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long-term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] 3GPP TS 23.288 (V16.0.0): "Architecture enhancements for 5G System (5GS) to support network data analytics services (Release 16)".

[i.2] 3GPP TS 23.288 (V17.0.0): "Architecture enhancements for 5G System (5GS) to support network data analytics services (Release 17)".

[i.3] 3GPP TS 23.501 (V19.0.0): "System architecture for the 5G System (5GS); Stage 2 (Release 19)".

[i.4] ETSI GR ENI 010 (V1.2.1): "Experiential Networked Intelligence (ENI); Evaluation of categories for AI application to Networks".

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[i.36] ETSI GS ENI 019 (V3.1.1): "Experiential Networked Intelligence (ENI); Representing, Inferring, and Proving Knowledge in ENI", 2023.

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3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the following terms apply:

AgentGPT: domain-specific model trained with domain-specific knowledge that matches the responsibilities of the AI Agent that it resides in

AI Agent: autonomous system that can interact with its environment to collect data, learn from the past experiences and subsequently use these to improve its decision-making capability in order to perform specific tasks

NOTE: As defined in clause 4.2.1 also [i.6], [i.7] and [i.8].

E2E Slice: logical network that provides a combination of specific network and network capabilities and network characteristics, supporting various service properties for network slice customers

E2E Slice Instance: set of Network Function, and Application Function instances and the required computing and communication resources that form a deployed E2E Slice

functional block: abstraction that defines a black box structural representation of the capabilities and functionality of a component or module, and its relationships with other functional blocks

intent policy: type of policy that uses statements from a restricted natural language (e.g. an external DSL) to express the goals of the policy, but does not specify how to accomplish those goals

NOTE: As defined in [i.29].

Large Language Model Meta AI (LLaMA): family of autoregressive large language models released by Meta AI starting in February 2023

NOTE: As defined in https://github.com/meta-llama/llama.

NetGPT: domain-specific model trained with data from core network domain

policy: set of rules that is used to manage and control the changing and/or maintaining of the state of one or more managed objects

NOTE: As defined in [i.29].

Quality of Experience (QoE): performance of users when using what is presented by a communication service or application user interface

Quality of Service (QoS): collective effect of service performances which determine the degree of satisfaction of a user of a service

NOTE: As defined in ETSI TR 121 905 [i.35].

Service Level Agreement (SLA): contract between a service provider and a customer that defines the service(s) to be provided and the level of performance to be expected

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

2B	To Business
2C	To Consumer
2H	To Home
ABI	Agent Based Interface
ADRF	Analytics Data Repository Function
AF	Application Function
AgentGPT	Agent Generative Pre-trained Transformer
AI	Artificial Intelligence
AI4N	AI for Network
AMF	Access and Mobility Management Function
API	Application Programming Interface
AR	Augmented Reality
BS	Base Station
CN	Core Network
CoT	Chain of Thought
CoT-SC	Self Consistency with Chain of Thought
DB	Data Base
E2E	End-to-End
eMBB	enhanced Mobile BroadBand
FB	Functional Block
GoT	Graph of Thought
GPT	Generative Pre-trained Transformer
HTTP	HyperText Transfer Protocol
ICT	Information and Communication Technology
IMU	Inertial Measurement Unit
IP	Internet Protocol
ISAC	Integrated Sensing And Communication
IT	Information Technology
KNN	K-Nearest Neighbour
KPI	Key Performance Indicator
KQI	Key Quality Indicator
LLM	Large Language Model
ML	Machine Learning
mMTC	massive Machine Type Communications
MSISDN	Mobile Subscriber Integrated Services Digital Network Number
N4AI	Network for AI
NetGPT	Network Generative Pre-trained Transformer
NF	Network Function
NFV	Network Function Virtualisation
NGMN	Next Generation Mobile Networks
NLP	Natural Language Processing
NRF	Network Repository Function
NWDAF	NetWork Data Analytics Function
O&M	Operation and Maintenance
OAM	Operations, Administration and Maintenance
PCF	Policy Control Function
QoE	Quality of Experience
QoS	Quality of Service
RAG	Retrieval Augmented Generation

RAN	Radio Access Network
RCS	Rich Communication Service
ReAct	Response and Action
RPC	Remote Procedure Call
SBA	Service Based Architecture
SLA	Service Level Agreement
SMF	Session Management Function
SMS	Short Message Service
TCP	Transmission Control Protocol
ToT	Tree of Thought
UE	User Equipment
URLLC	Ultra-Reliable Low-Latency Communication
XR	Extended Reality

4 AI Agents Based Next Generation Network Slicing

4.1 Revolution Trend

4.1.1 New Usage Scenarios of Future Mobile Network

The NGMN white paper [i.27] describes new use cases and services that need to be supported by 6G networks. These new use cases and services require 6G networks to provide ultra-high performance while connecting humans, machines and various other entities. This calls for a variety of new capabilities and requires 6G networks to have enhanced on-demand customization capabilities to adapt to the wide range of applications autonomously. These include immersive multimedia and multi-sensory interactions, highly intelligent industrial applications, integration of physical and virtual worlds through digital twins, and ubiquitous intelligence and computing.

As described by Recommendation ITU-R M.2160-0 [i.28], it is expected to integrate sensing and intelligence capabilities, empowered with AI and machine learning, into networks to keep up with the steady progress and fast spread of such. As stated in the same document, [i.28] could serve as an AI-enabling infrastructure that can provide services for intelligent applications listed above. Therefore, 6G networks are expected to face great challenges in the future as intelligent applications will take numerous forms and may be triggered based on user intents.

4.1.2 Potential Improvements of 5G Network Slicing

4.1.2.1 Network Slicing and NFV

5G systems are known for their heterogeneity in service categories, such as enhanced Mobile Broadband (eMBB), Ultra-Reliable Low-Latency Communication (URLLC), and massive Machine Type Communications (mMTC). Such a broad diversity in service requirements calls for customized solutions by 5G network operators for their customers, which has primarily been addressed via the network slicing concept. Together with Network Function Virtualisation (NFV), network slicing allows the 5G mobile network operators to build dedicated, virtualized and logical networks on a common physical infrastructure to meet the diverse communication requirements of their customers.

In contrast to 5G networks, which are designed for providing only communication service to their users, 6G networks are envisioned to extend their services beyond connectivity. More specifically, 6G networks are expected to add AI, compute, and sensing to their services on top of connectivity, introducing new types of resources, new functionalities, and design considerations. This calls for a more flexible, autonomous, and generalizable network slicing framework for the configuration, deployment and management of such slices of new type. Since this comes with increased complexity rendering the conventional methods insufficient, the deep integration of AI/ML technology into the operation of 6G networks offers a promising solution.

4.1.2.2 Network Data Analytics Function (NWDAF)

3GPP has introduced a new logical function entity in 5G, known as the Network Data Analytics Function (NWDAF), into the 5G network architecture [i.1]. The NWDAF can interact with other core network functions such as the Application Function (AF), Policy Control Function (PCF), Access and Mobility Management Function (AMF), and Session Management Function (SMF) to provide network data analytics services, network intelligence, and automation capabilities for 5G networks.

These services include receiving network data analytics requests from other core Network Functions (NFs), collecting and analysing data using AI algorithms to generate network analytics results, and delivering these results to the requesting (i.e. consumer) NF.

Each NF leverages the network analytics provided by the NWDAF to monitor the operational status of the 5G network and the User Equipment (UE), enabling closed-loop network control and optimization of communication services. For example, the NWDAF supports analytics and event exposure services related to network service experience, network performance, slice load, NF load, UE mobility, communication events, abnormal events, Quality of Service (QoS) sustainability, user data congestion, and more.

3GPP has enhanced the 5G network data analytics framework over multiple releases by introducing the logical functional division of the NWDAF and defining their interactions. It also facilitates cooperation between multiple NWDAF instances for model training and sharing, while incorporating new functional entities to improve data collection efficiency and enhance real-time performance [i.2]. Several enhancements have been proposed for the NWDAF, particularly to support flexible deployments (centralized, distributed, etc.), enable collaboration between different NWDAF instances, decompose NWDAF functionality, and achieve tighter integration with the UE (e.g. analysis of session load and signal quality). Additionally, the NWDAF has been further integrated with edge devices to optimize network operations.

Despite all of the aforementioned features, the existing capabilities of NWDAF primarily focus on analytics centred around better connectivity. As it has been explained in clause 4.1.2.1 on 6G network slicing, the considerations beyond connectivity service (e.g. compute, sensing, AI) are not fully incorporated into the NWDAF's services. For instance, idle resources within the network infrastructure will be important and needed to embrace the native integration of AI and deployment of foundation models towards an autonomous and optimized network operation. Therefore, 6G systems are to make better use of under-utilized resources in the network, contributing to sustainability targets and further expand the profitability of mobile networks for mobile network operators.

4.1.2.3 AI Agents

The current 5G core network deeply integrates telecommunications networks and IT technologies by cloud deployment, making the network architecture more agile and open. Therefore, network operations have become more efficient and automated. Looking towards the 6G era, in which the diversity of network services, resources and capabilities are envisioned to increase, standardized pre-defined processes based on scenario-specific expert knowledge are no longer sufficient for the efficient operation of the network. This is due to the significant increase in service and resource diversity required along with increased flexibility that is needed in service requirements and network functionalities. Together, these bring unprecedented challenges to the network architecture design, especially for the core networks.

Agentic AI is a new class of artificial intelligence systems designed to act with autonomy, making decisions and taking actions without having been specified in advance or without direct human intervention. These systems are capable of processing vast amounts of data, reasoning (the process of reaching understanding), and adapting to real-time changes in their environment. Hence, AI agents-based systems are a promising solution towards a more generalized and extensible design of 6G systems. Key features of Agentic AI systems include autonomy in decision-making, goal-oriented behaviour, continuous learning and adaptation, proactive planning and execution, as well as advanced reasoning capabilities According to [i.26], systems integrating AI agents "are characterized by the ability to take actions which consistently contribute towards achieving goals over an extended period of time, without their behaviour having been entirely specified in advance". This will render the mobile network a fully autonomous networks, as specified in [i.33], where any scenario (although unknown from before) can be supported due to excellent adaptability and knowledge reasoning capabilities of Agentic AI.

Developing and deploying an AI Agent is not a straightforward process, as such systems are complex by design requiring various functional modules and mechanisms to realize its value to the full extent. These typically include different decision-making models, vector databases, tool libraries, self-reflection and self-evolving mechanisms. As of today, AI agents have not been considered and deployed in 3GPP systems.

An example use case to be studied for the adoption of AI agents in 6G core is the optimal and flexible design of End-to-End (E2E) network slices. In such a setting, AI agents that are empowered with Large Language Models (LLMs) can be employed as an interface to support human operators in defining high-level intents and setting up optimization tasks as external input.

4.2 AI-Core Concept: AI Agents-Based Next Generation Core Network

4.2.1 AI Agent Introduction

AI Agent is defined as an autonomous system that can interact with its environment to collect data, learn from the past experiences and subsequently use these to improve its decision making capability in order to perform specific tasks [i.6], [i.7] and [i.8].

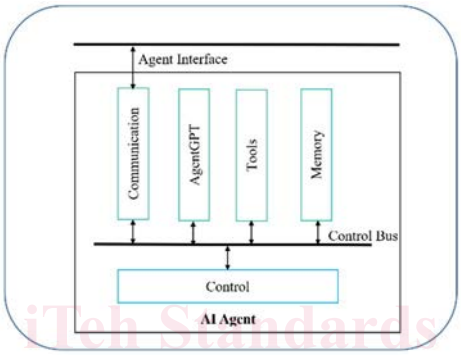

Figure 4.2.1-1: General Framework of an AI Agent

Figure 4.2.1-1 depicts a general framework of an AI Agent that is made up of the following logical components:

- Communication: The interface of an AI Agent to communicate with external components, supporting various networking standards and protocols, such as TCP/IP and HTTP. The communication block handles the input/output operations.

- Memory: Collects and stores data for the AI Agent for task continuity and self-improvement, including short-term memory (external input, historical inference result, temporary information, etc.) and long-term memory (knowledge, profile, etc.). The memory sub-component plays a crucial role in accelerating and agent's learning and adaptation capabilities, thereby, contributing to reducing computational complexity and energy efficiency. Such mechanisms have been used in the existing literature, not necessarily to design and implement AI agents, for storing/caching reoccurring problems that have already been solved in the past, also referred as dynamic programming [i.31], [i.34].

- AgentGPT: a domain-specific model with less parameters compared to the 'NetGPT' (see clause 4.4). The AgentGPT is trained with domain-specific knowledge (e.g. on a certain problem class) that matches the responsibilities of the AI Agent that it resides in.

NOTE 1: The name "AgentGPT" does not reflect any publicly available library or service and has solely been selected to emphasize the fact that it resides inside an AI Agent, also to easily distinguish from NetGPT.

NOTE 2: The name "AgentGPT" is also chosen because an AI Agent system does not mandate either the use of an LLM or an Agent to be embodied in an LLM. Since AgentGPT does both, the name has increased significance.

- Tools: Functions and APIs that are used to obtain additional information or abilities that are not present in the AgentGPT. These can include search engines, databases, calculators, calendars, maps, APIs for specific services, and other task-specific utilities.

- Control: The executive function of the agent that orchestrates the interaction between all components. It manages the flow of information, decides when to use AgentGPT or specific tools, coordinates memory access and updates, and implements the agent's overall strategy and decision-making.