HELLENIC REPUBLIC
National and Kapodistrian University of Athens

AI: An Enabler for 6G Services

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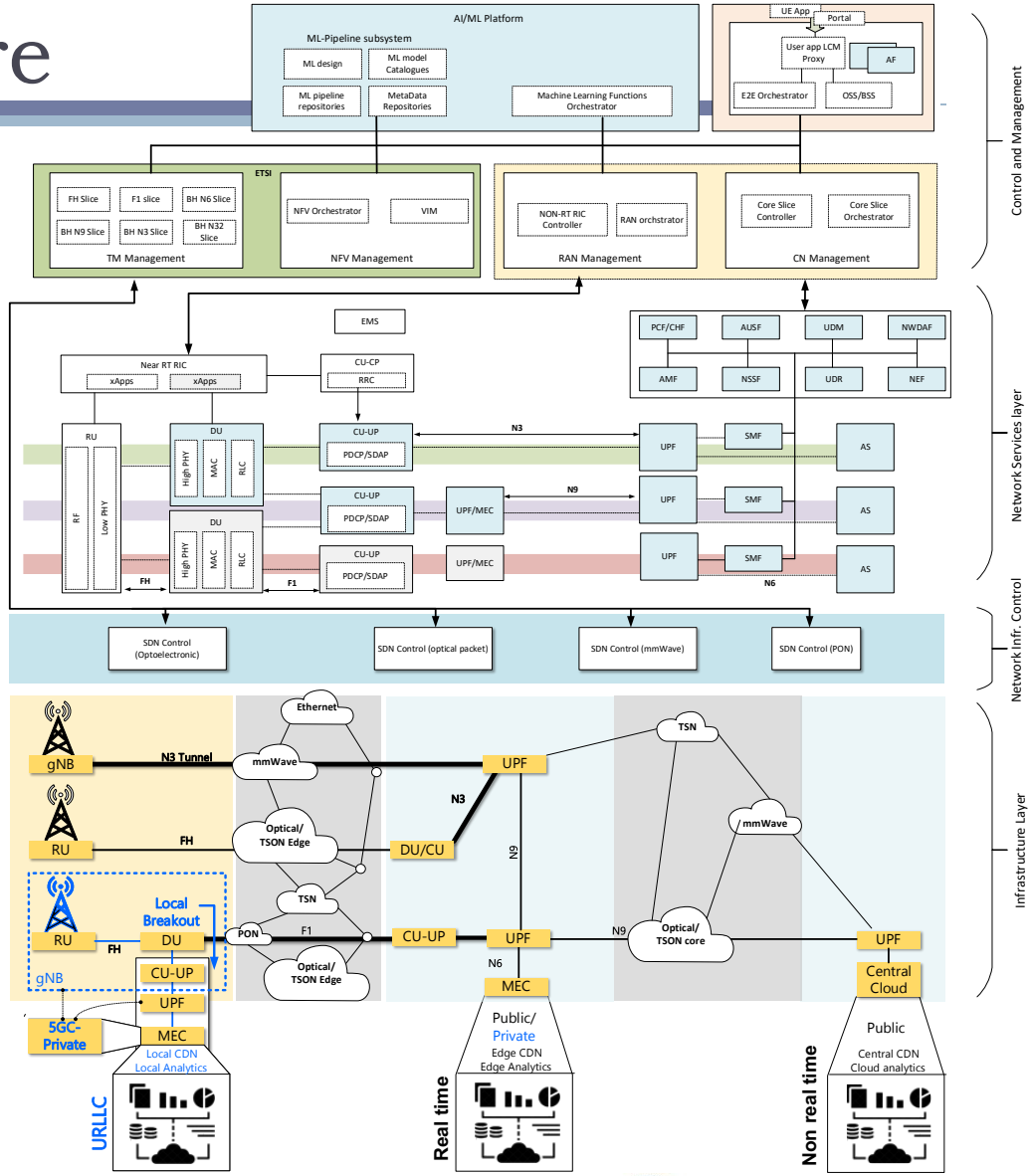
Motivation

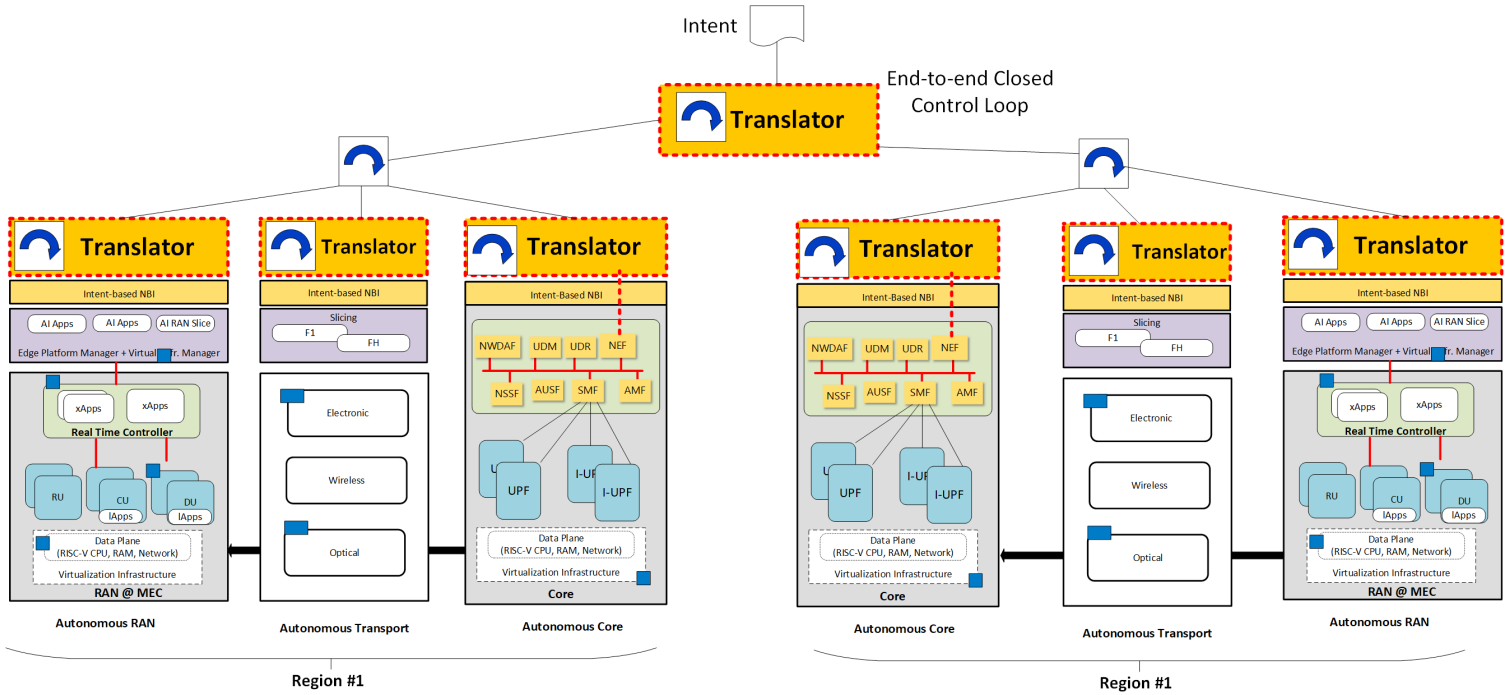
- 6G will support a large variety of applications and offer improved performance in comparison to 5G
  - Peak data rates, latency, energy efficiency, device density, IoT connectivity etc
- Increased Intelligence and flexibility through wider adoption of Artificial Intelligence (AI) and Machine Learning (ML)
- 6G will offer ubiquitous infrastructures integrating the most advanced network and compute technologies in a flexible and scalable manner
- In 6G, optical networking will play bigger roles than any previous generation
- Increased complexity
  - challenges: integration of cloud/edge/far edge computing and networking technologies, big data…
- Dedicated slices customized for various business demands (verticals):
  - programmability through softwarization, virtualization, open sources and open interfaces
- E2E Orchestration, Management and Control
  - require enhanced concepts, methods and technologies

Overall Architecture

- Multi-layer Architecture supporting:
  - Provisioning of services over multi-technology transport network
  - Different deployment options
    - placement of RU/DU/CU/5GC/AS entities at locations in the network
  - End-to-end orchestration that interacts with the different building blocks of the system (vertical/horizontal)
    - enabling 6G systems to operate in an optimized manner



Need for Autonomous Operation: Intent-Based Network (IBN)



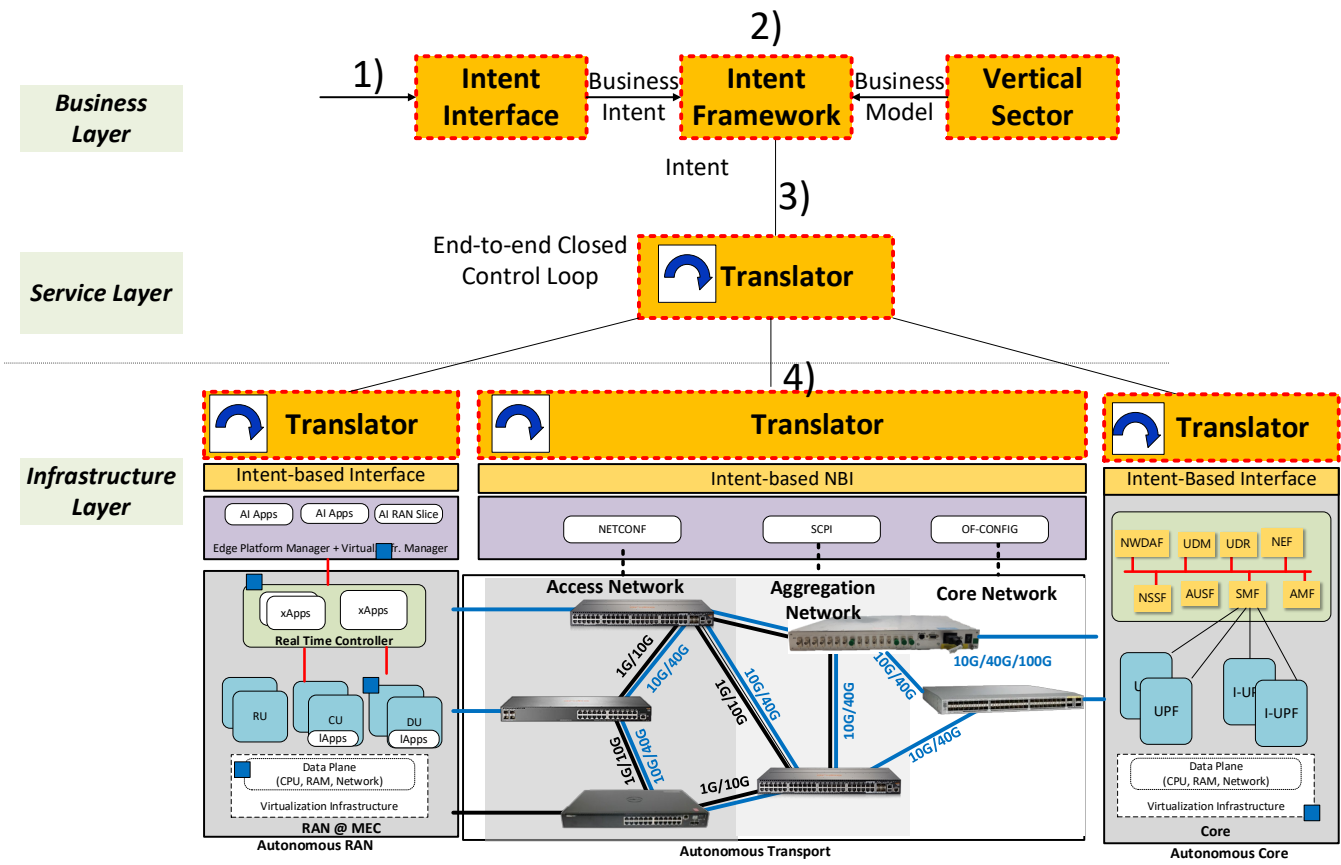
- IBN transforms a hardware-centric, manual network into a controller-led network
  - it captures business intents and translates them into policies
  - these can be automated and applied across the network
  - a software-enabled automation technique
  - combines ML, AI, analytics, and orchestration to improve network operations and uptime

https://www.cisco.com/c/en/us/solutions/intent-based-networking.html

Ref: ITU-T "Scenarios and Requirements of Intent-Based Network for Network Evolution"

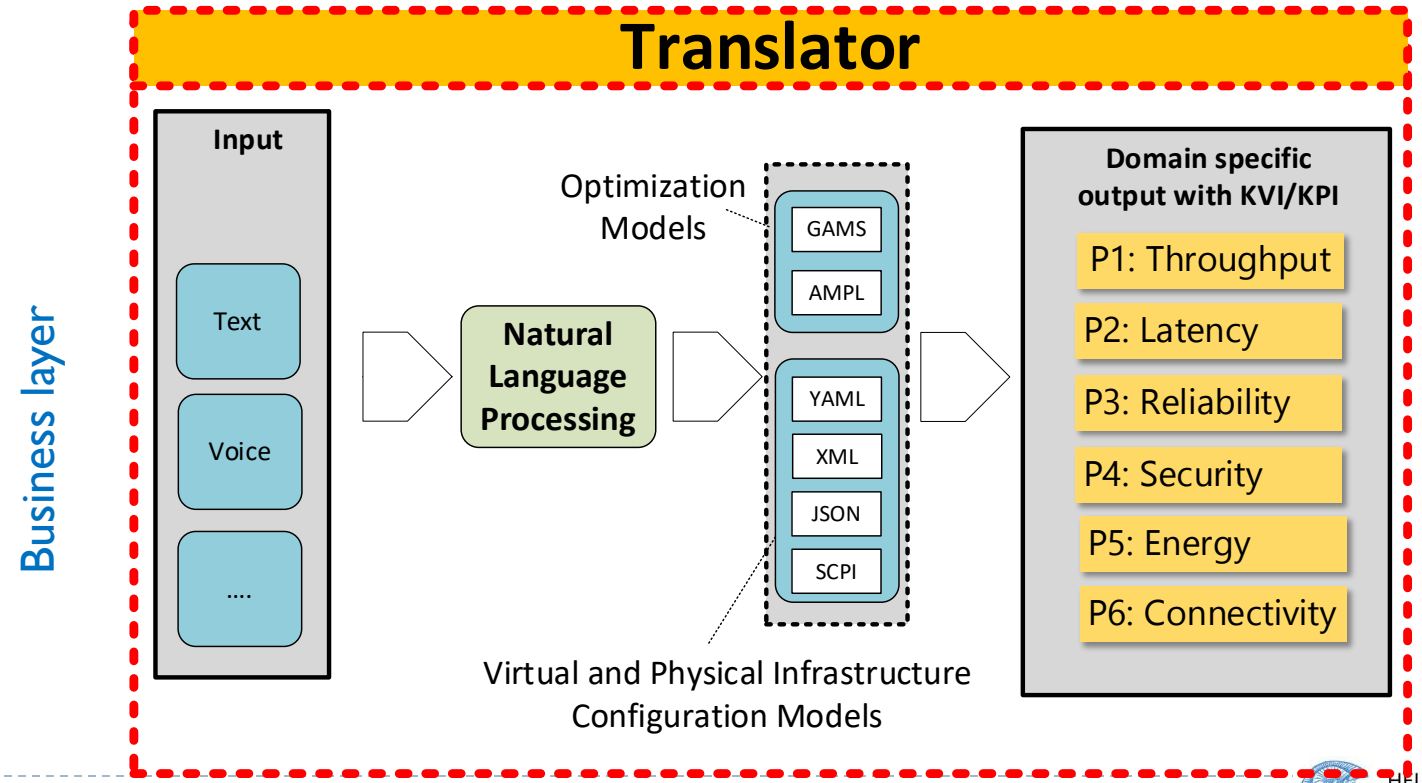
IBN Process

1. Intent Interface: The vertical industry manager uses this interface to input business intent
2. Collect the intent
3. Translate the high-level intent into network-specific requirements
4. Send the intent into the network controller using APIs
5. Deliver the network service



Intent translation

- Business layer implementation
- Business objectives i.e. the human/vertical ***inputs*** are translated to the domain ***specific programming language parameters*** through Natural Language Processing (NLP)
  - This functionality has been implemented using the "Translator" AI model

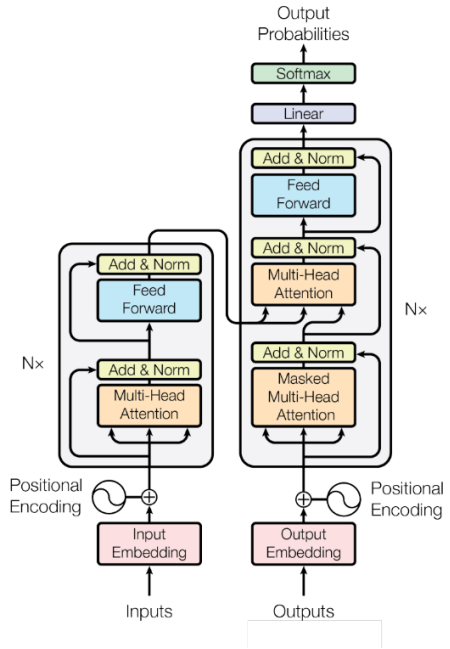


Implementation of NLP

- Example of NLP processing: based on "Transformers" AI model
- Translate from the human/vertical inputs to the domain specific programming language parameters based on Natural Language Processing (NLP)
  1. **Bidirectional Encoder Representations from Transformers** (BERT): uses the encoder part of the transformer architecture so that it understands semantic and syntactic language information – encode high level intents provided by users
  2. **Generative Pre-trained Transformer (**GPT) decoders are used to generate the response

BERT

Encoder



GPT

Decoder

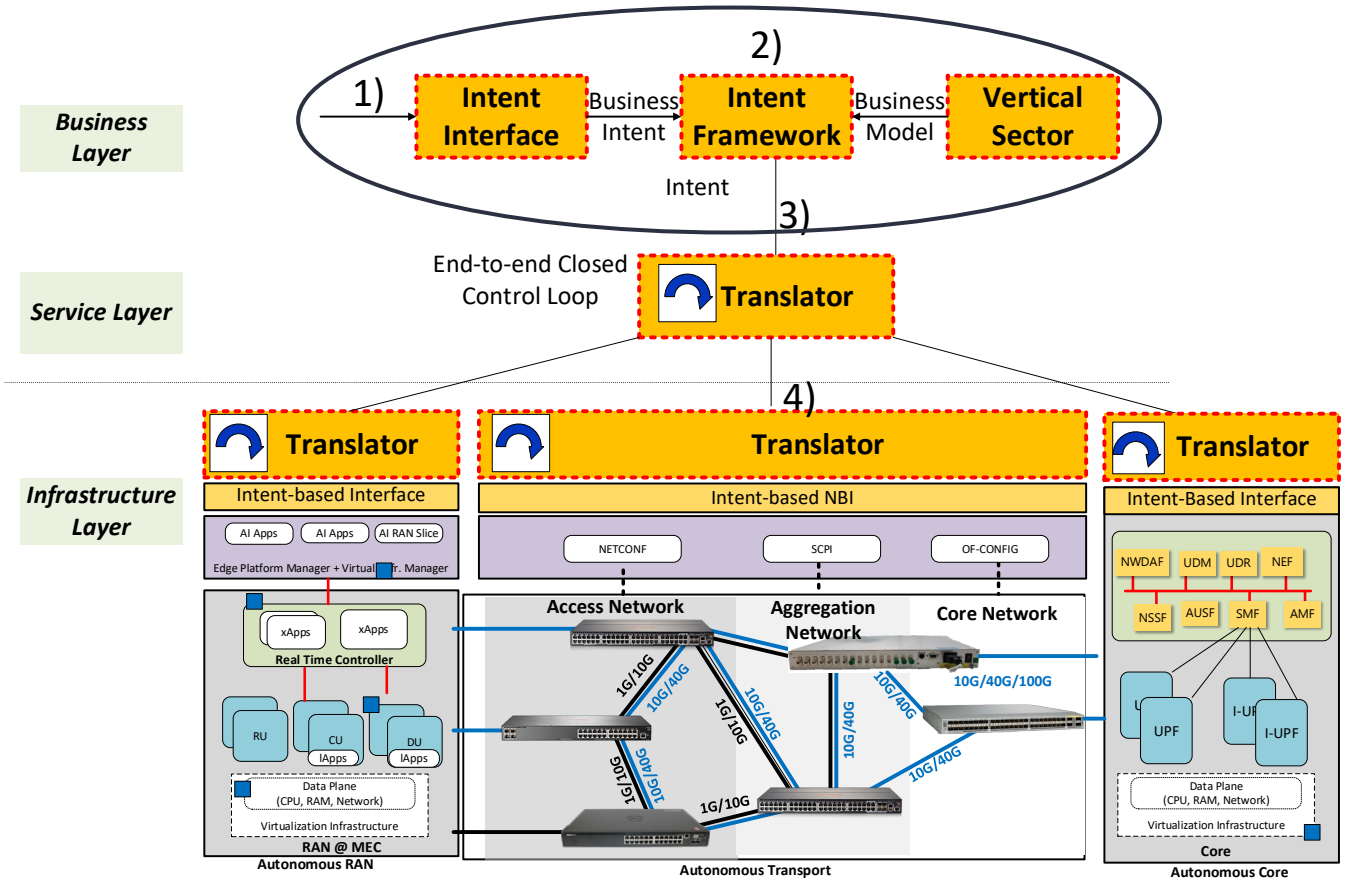
Ashish Vaswani et al., 2017. "Attention is all you need", In Proceedings of the 31st International Conference on Neural Information Processing Systems (NIPS'17). Curran Associates Inc., Red Hook, NY, USA, 6000–6010.

Implementation Example: Business Layer

- Set up an E2E slice based on a high level command provided by free text
  - e.g. **"Set *up an Energy Aware URLLC slice*"**

"Business Layer"

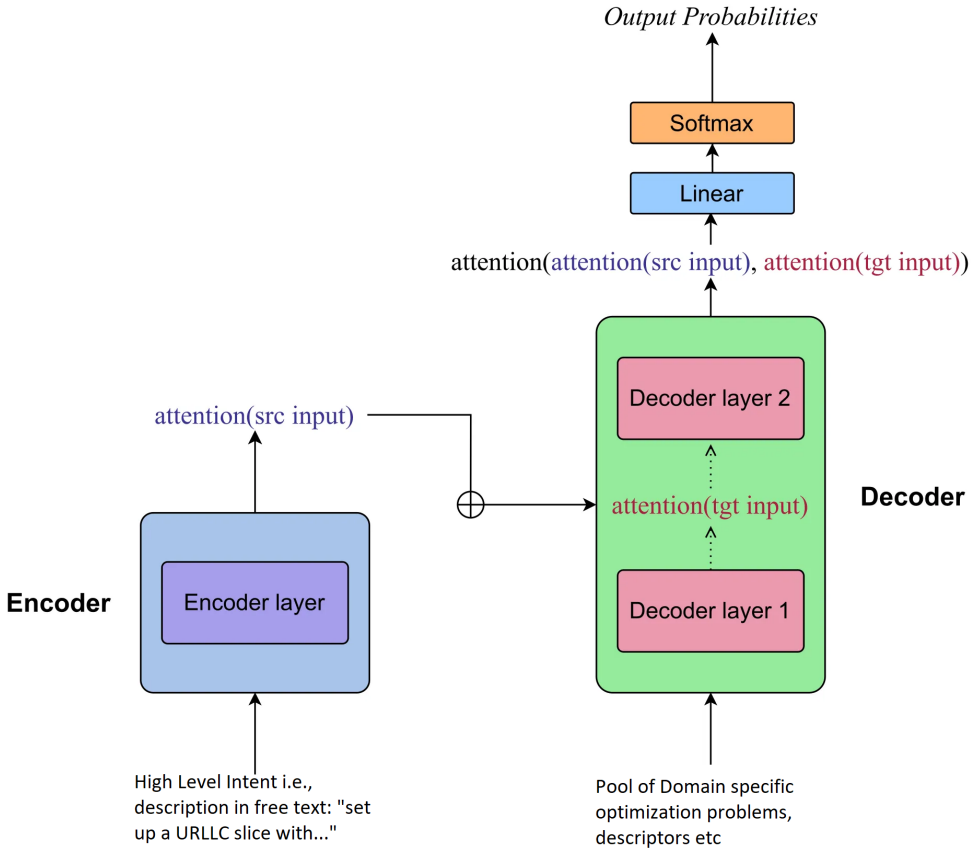
- the transformer AI model "generates" the appropriate optimization code to be used to identify the corresponding URLLC slice



A. Tzanakaki, M. Anastasopoulos and V. M. Alevizaki, "Optical Transport Networks Converging Edge Compute and Central Cloud: An Enabler For 6G Services", OFC 2024

Implementation Example: Business Layer

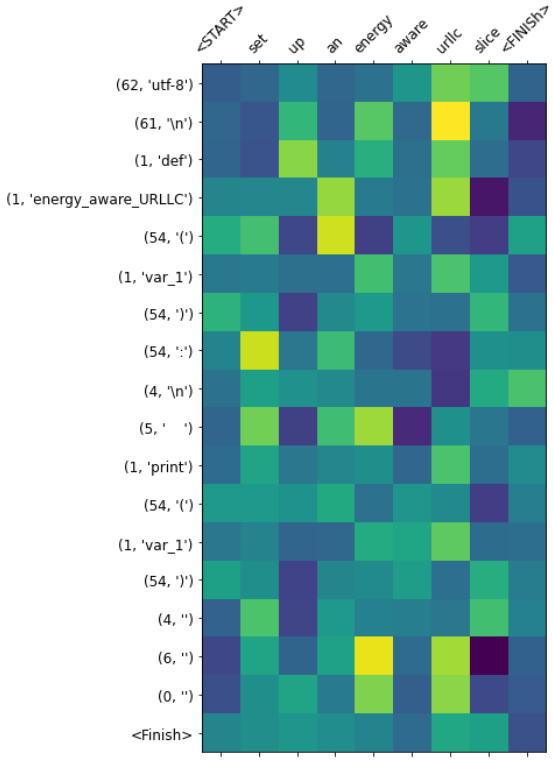
- NLP model translates high level intents into optimization code (e.g. ILP model) for E2E slice creation used by the orchestrator
- Implementation based on "Transformers"
  - Input: High level "Intents"
  - Output: Code implementing the "Intent"
  - Selection criterion: Output probabilities (Intent Attention weight) i.e. Probability to select the correct code / descriptor from the available pre-defined code library

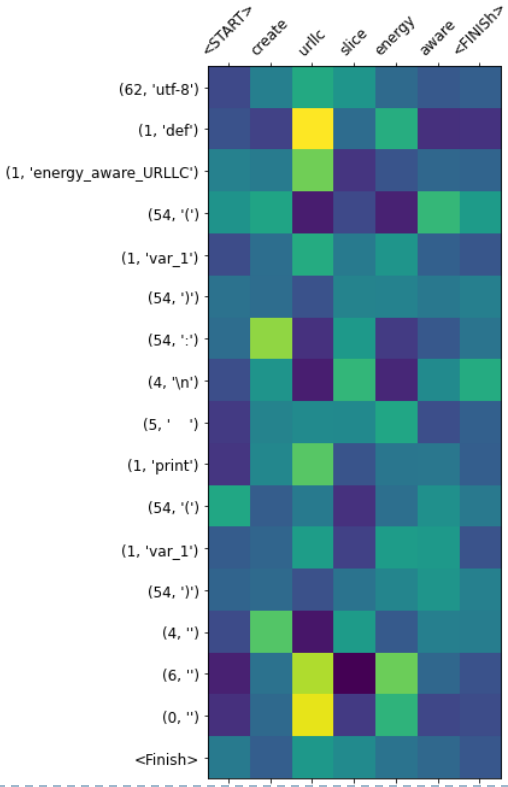


Adapted from https://www.tensorflow.org/text/tutorials/transformer

Implementation Example: Optimization Code

- User requests in free text to "Set *up an Energy Aware URLLC slice*"
- The transformer "generates" the appropriate optimization code to be used by MANO
  - selects from the available code libraries

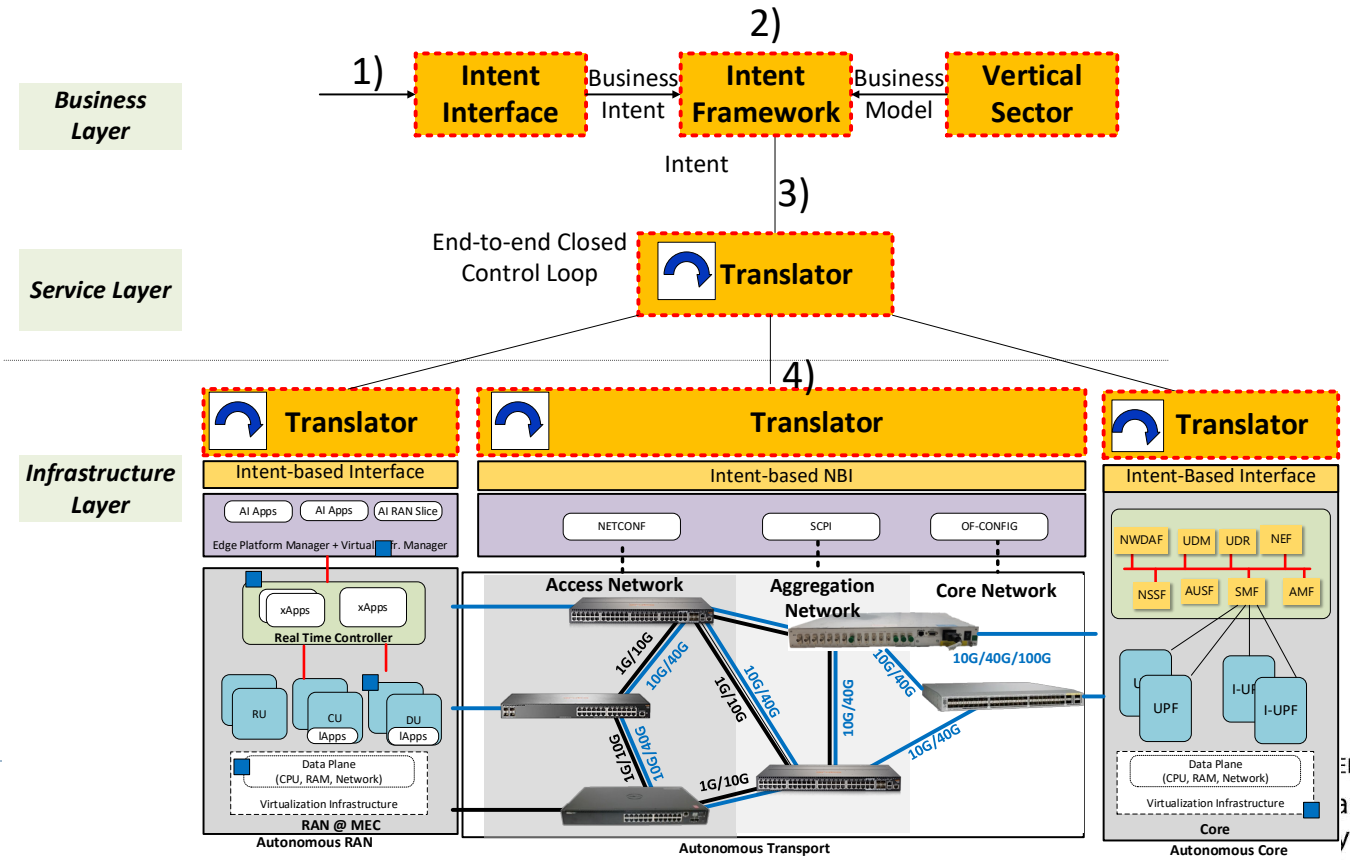




Similar output is produced with different syntax i.e., "Create URLLC slice energy Aware"…

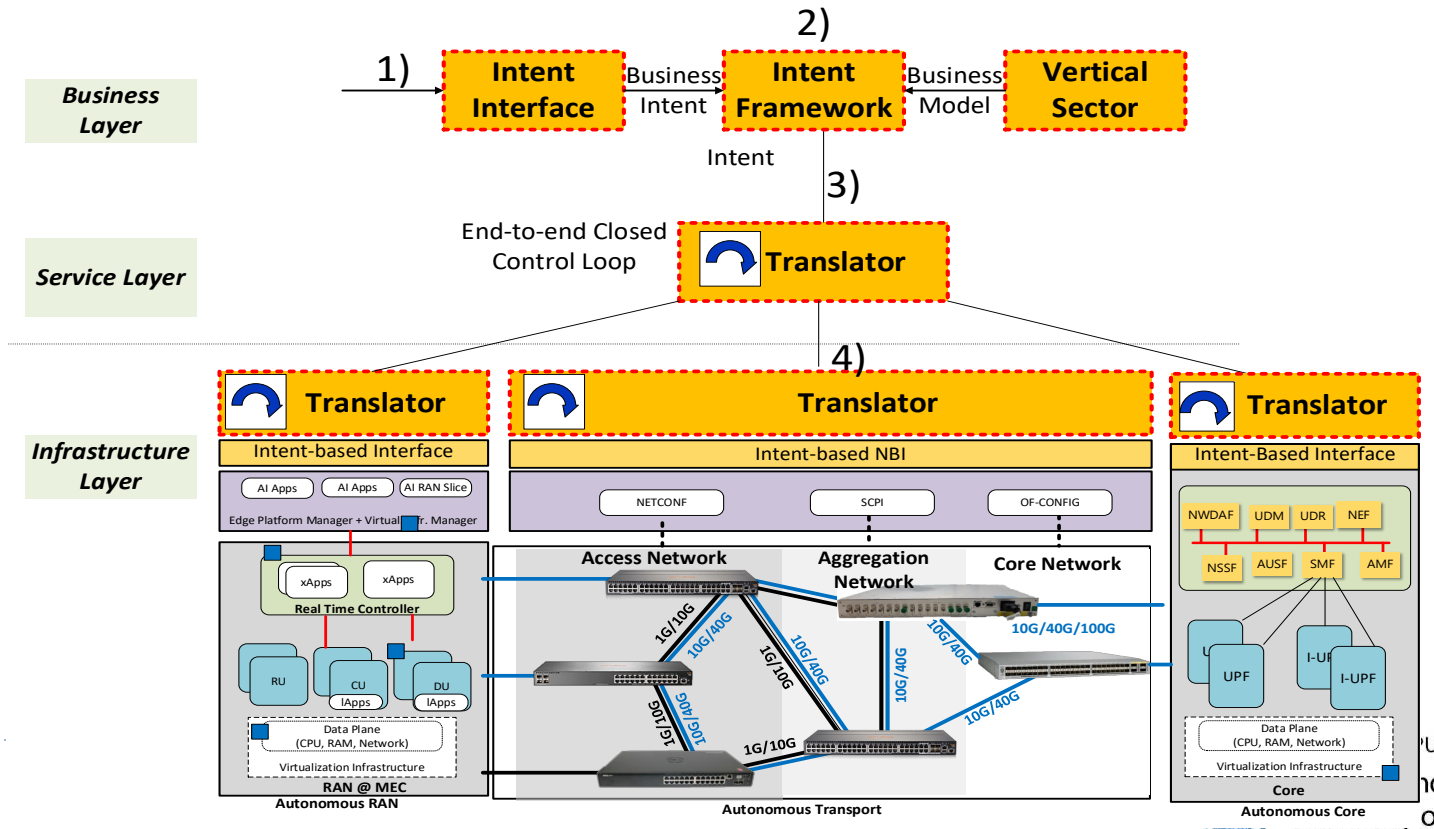
Implementation Example: Service Layer

- The optimization output is used by the service layer to auto generate the relevant configuration files for the UPF nodes, along with the necessary interfaces
  - Network Slice Templates (NST), Network Service Descriptors (NSD), and Virtual Network Function Descriptors (VNFD) required by Open Source MANO

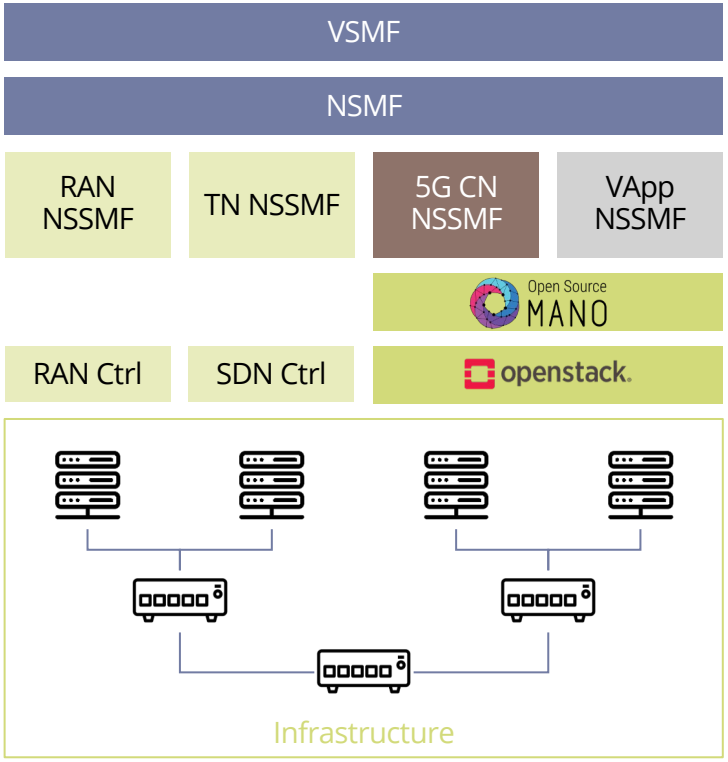


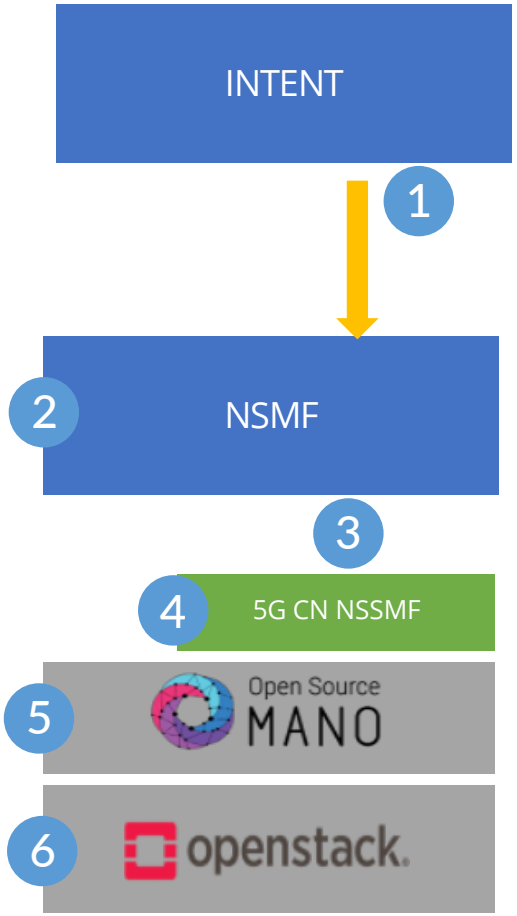
Implementation Example: Infrastructure Layer

- The infrastructure layer translator generates the commands and config files to establish transport network connectivity
- The Translator creates the necessary OpenFlow Configuration and Management Protocol (OF-CONFIG) and Network Configuration Protocol (NETCONF) compliant configuration files providing the physical connectivity for the virtual links defined in the upper layer



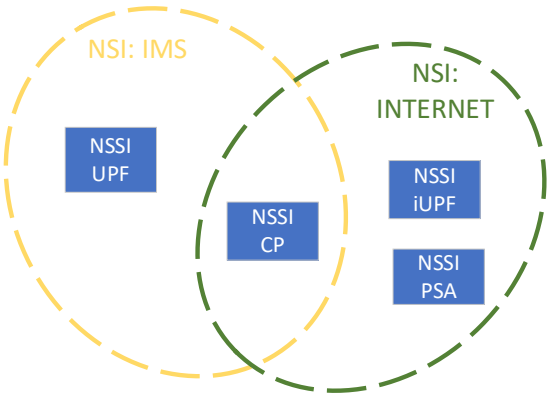
Experimental Implementation: Enhanced OSM with IBN

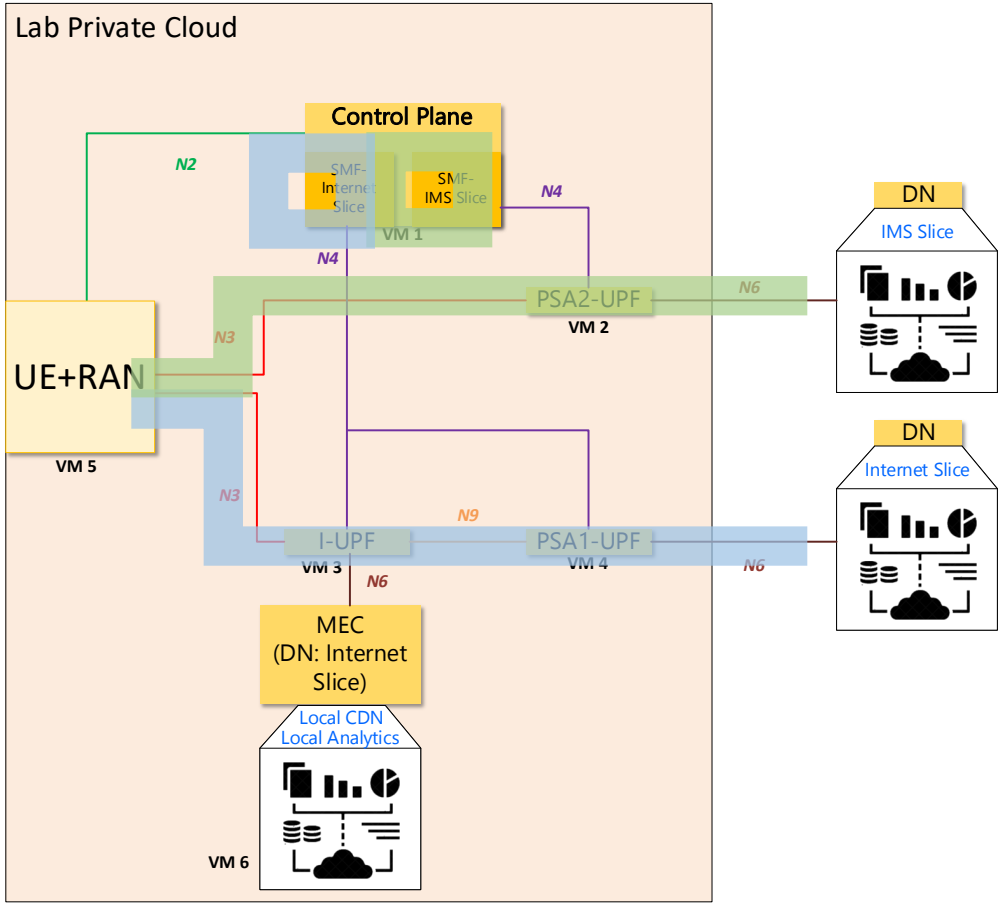




Experimental Implementation: 5G Slice Deployment

- Instantiation of two isolated slices
  - Slice IMS:VM1 (Core/SMF)+ VM 2 (UPF)
  - Slice Internet:VM1 (Core/SMF) + VM3 (I-UPF) + VM4 (UPF)
- Shared CP
- Different UP paths





Conclusions

- Motivation
- 5G/6G Architecture
- Need for Autonomous Operation
  - Intent Based Networking
  - AI a key enabler
- Implementation Example of IBN over a 5G infrastracture
  - E2E slicing
  - Enhancing Orchestration Process with IBN

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Thank you!

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ECO eNET

6G SNSES