Intelligent programmable data planes to optimize application delivery in 6G networks

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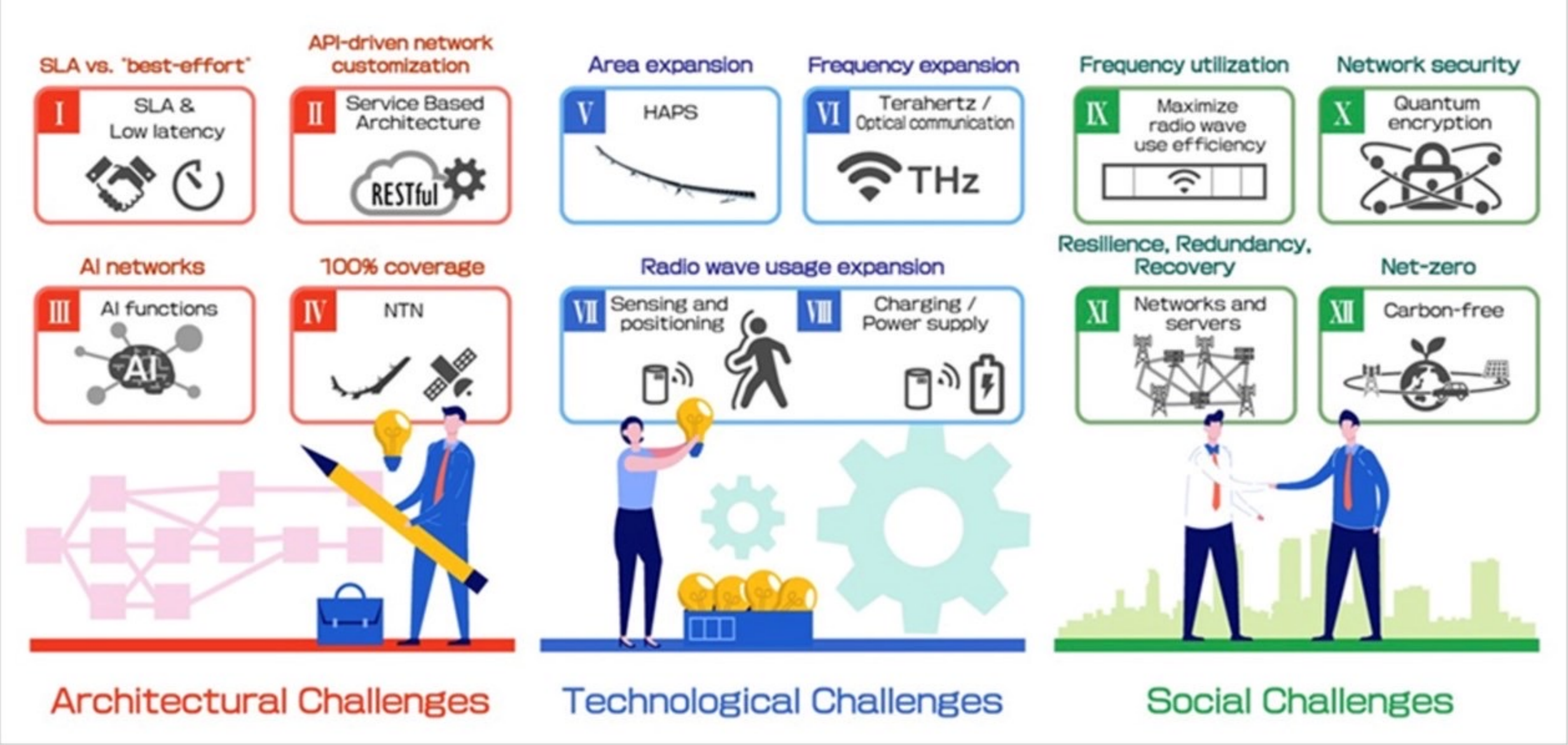
A view of the 6G challenges



Ref: Softbank

Focus of the presentation: intelligent data planes as 6G enablers

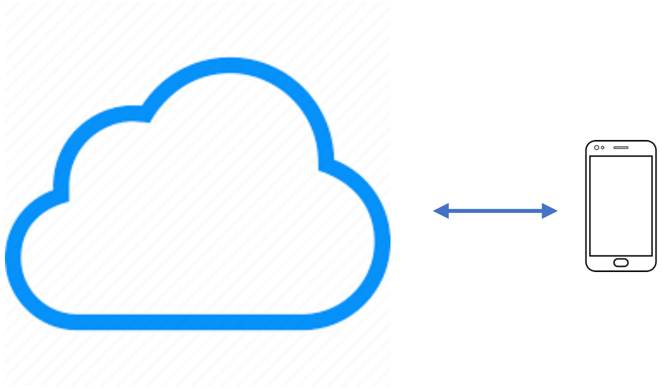
- In-network computing
- Functional distribution
- Data driven systems
- Joint optimisation of application and networks
- Use of machine learning and artificial intelligence
- Digital twins

A common thread: distribution, coordination, federation

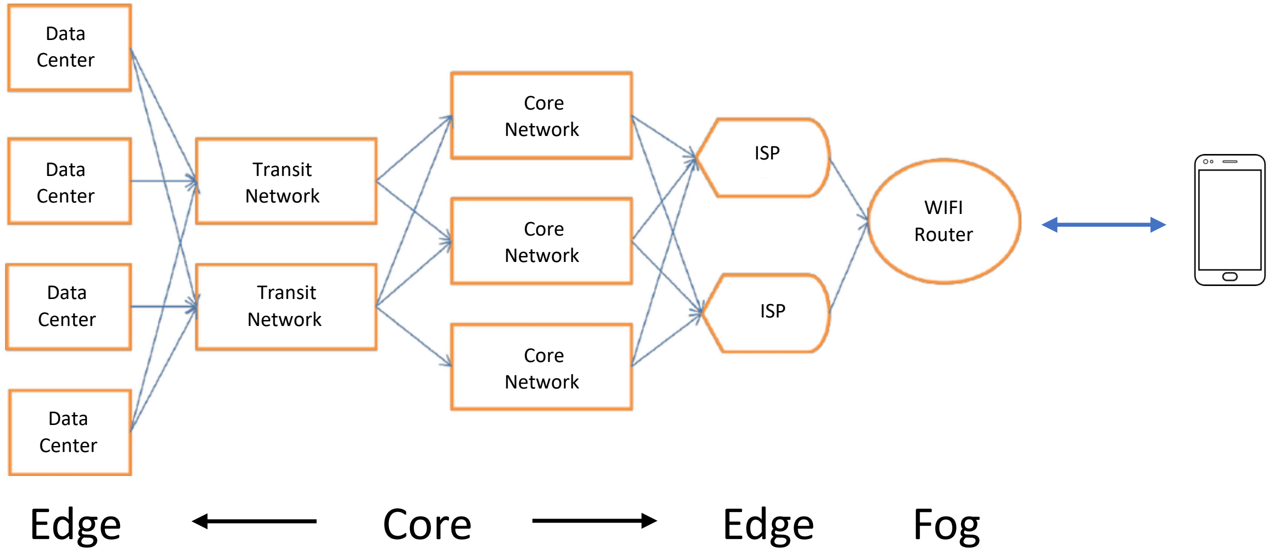
Trends

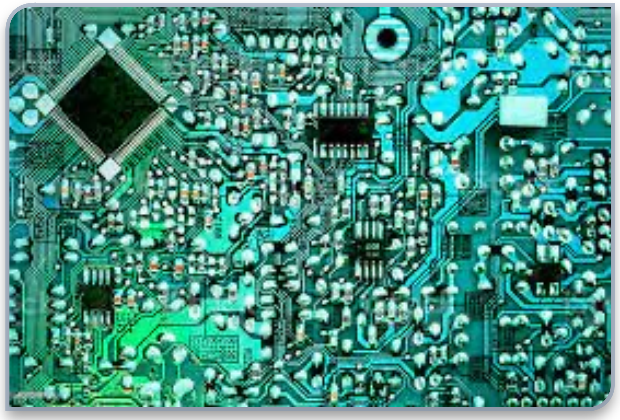
- Next Generation networks: NDN/ICN/CFN
- AI/ML and data-driven systems (supervised and self-supervised)
- IoT/AIoT and sensing
- Fog/edge/cloud functional decomposition
- Internetworking and distributed systems (network of networks)
- SDN/NFV and the softwarisation of networking
- Containerized computing
- Green computing

From the “cloud” to the fog/edge/cloud continuum



Focus on what a service or application needs (“the life of a packet”)





In-network computing:
the network as a computer board, the Internet as its operating system.

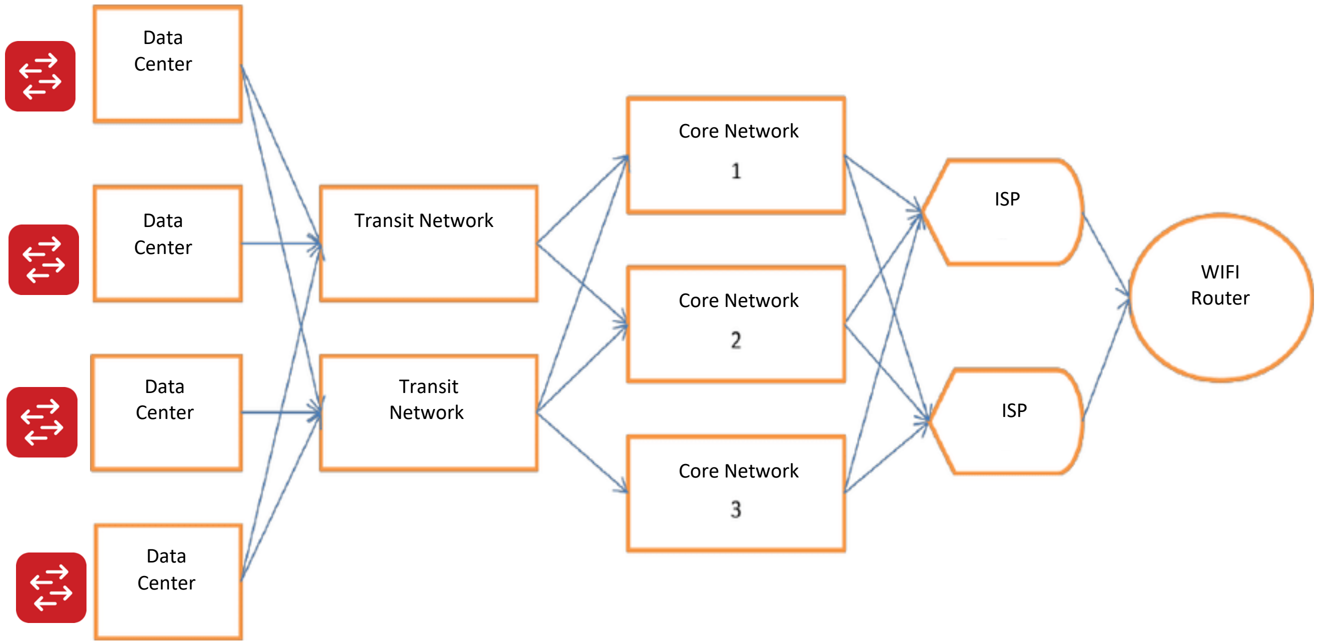
In-Network Computing

- Build on the recent development of programmable data planes and resource discovery to improve the performance of network devices
  - Identify critical events to improve reliability or manage system performance
- Use protocols, programming languages and abstractions to implement network functions inside nodes including:
  - PISA architecture and P4 language
  - The Network OS
- In-network functionality, includes but not limited to:
  - Computing, caching, managing, control and security
- Important applications in data-driven systems/IoT, AI/ML and digital twinning

Requirements

- Joint optimization of networking, computing and storage.
- Horizontalization of data plane to enable cross functional distributed application and cognitive intelligence.
- Secure and robust common semantics between applications/service and infrastructure resources.

In the beginning…



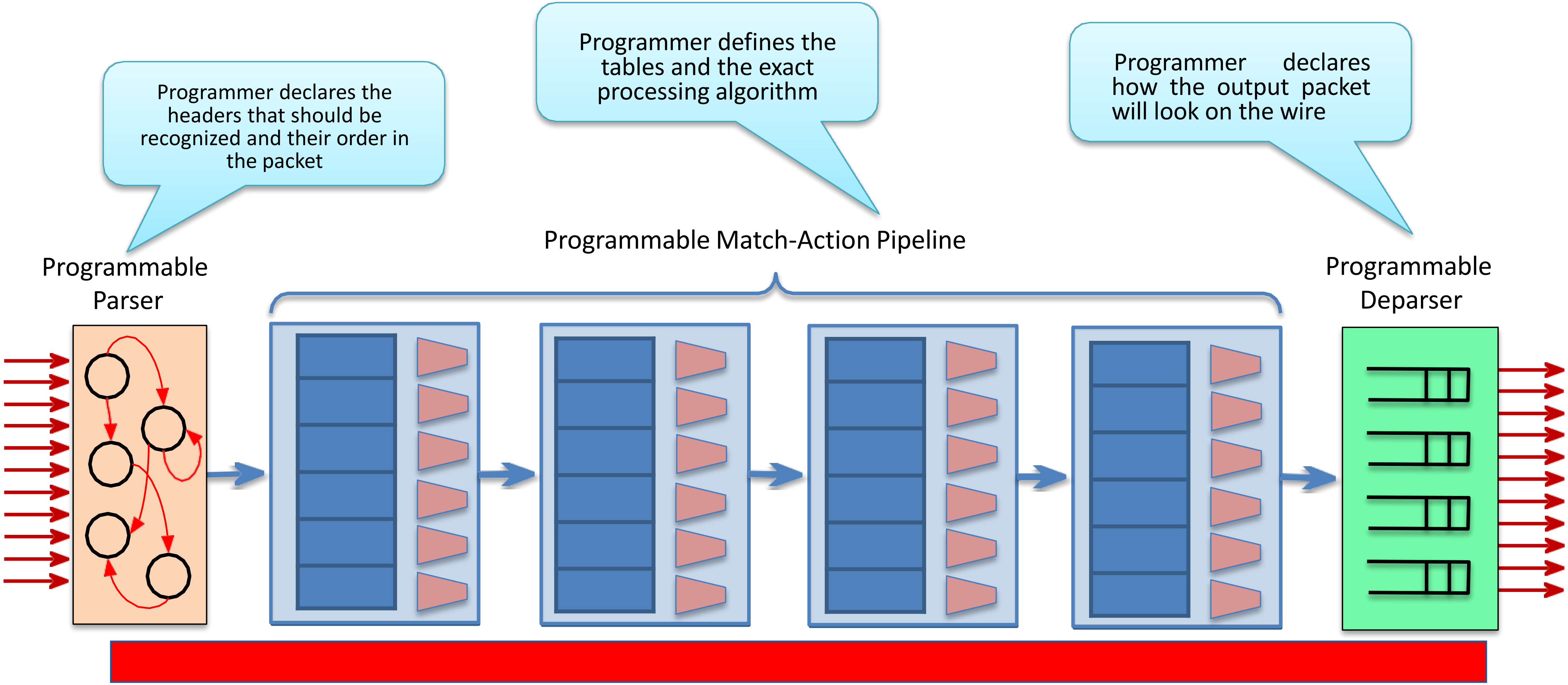
- Basic application in datacenters: filter packets (at line speed) based on headers (and metadata) for fast match/action.
  - Identify critical events to improve reliability or manage system performance.
  - Workload balancing.

Programmable Network Devices

- *PISA: Flexible Match Action ASICs*
- NPU
- NIC
- CPU
- FPGA

These devices let us tell them how to process packets.

PISA: Protocol-Independent Switch Architecture



$P4_{16}$: Language for the PISA Architecture

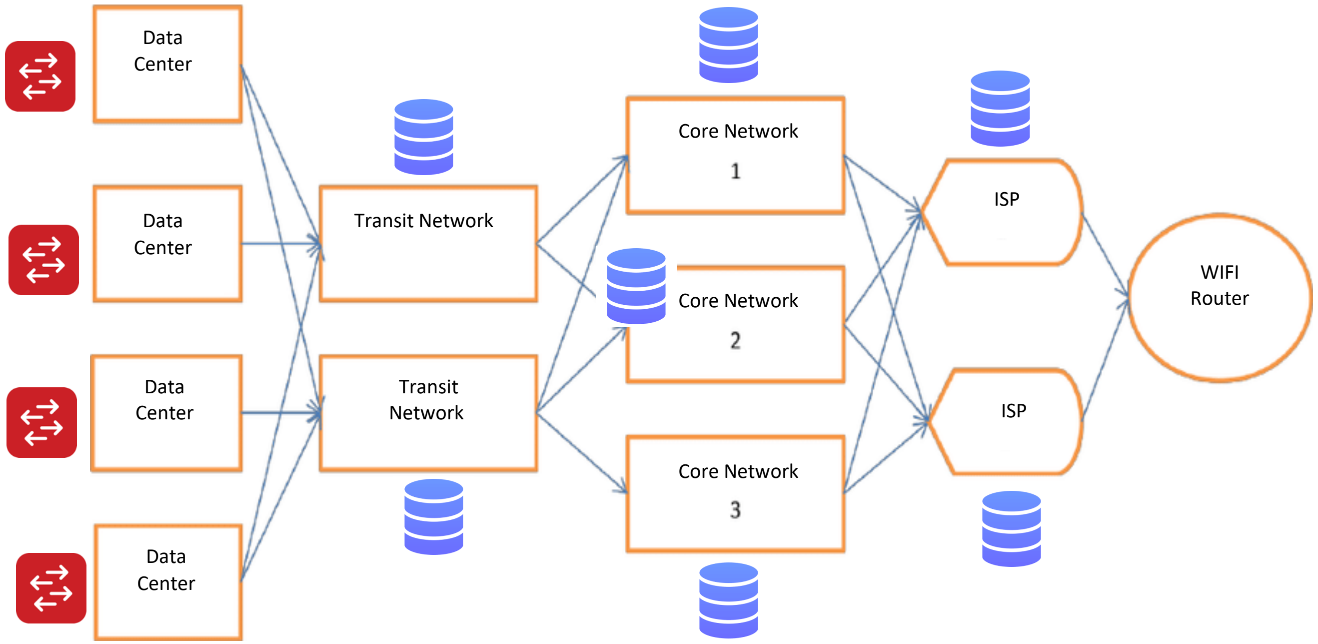
- Programming Protocol-independent Packet Processors (P4) :
  - Open source, domain-specific programming language for network devices
- Specifies how data plane devices (switches, routers, NICs, filters, etc.) process packets.
- Uses a C-like syntax

```
#include <v1model.p4>
/* HEADERS */
struct metadata { ... }
struct headers {
  ethernet_t    ethernet;
  ipv4_t        ipv4;
}
/* PARSER */
parser MyParser(packet_in packet,
          out headers hdr,
          inout metadata meta,
          inout standard_metadata_t smeta) {
  ...
}
/* CHECKSUM VERIFICATION */
control MyVerifyChecksum(in headers hdr,
                         inout metadata meta) {
   ...
}
/* INGRESS PROCESSING */
control MyIngress(inout headers hdr,
                  inout metadata meta,
                  inout standard_metadata_t std_meta) {
  ...
}
```

Data is the fuel of the 21st century

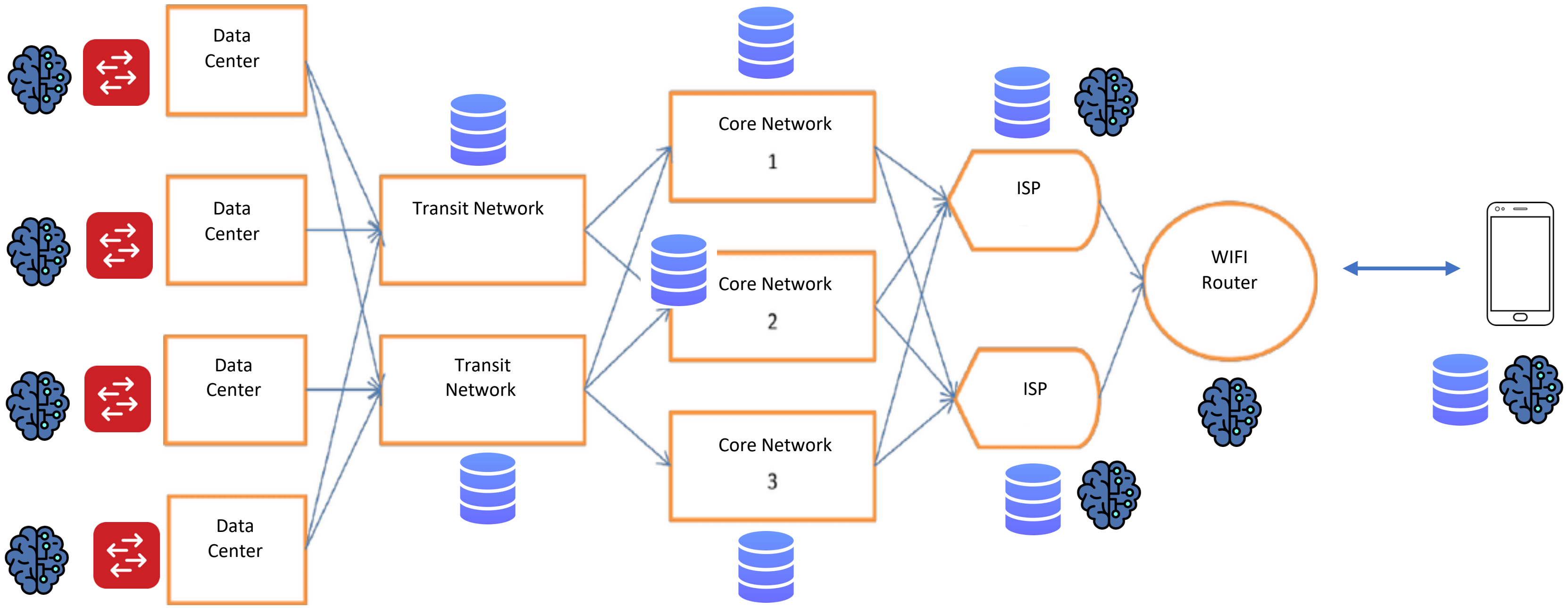
Telemetry for in-network data acquisition

- NSF 2020-2025 Broadband trend report identified data as the most needed research tool in technology, economics and social science in the 6G era.
  - To predict performance and manage networks
  - For new models of broadband penetration
  - For adding intelligence in the network

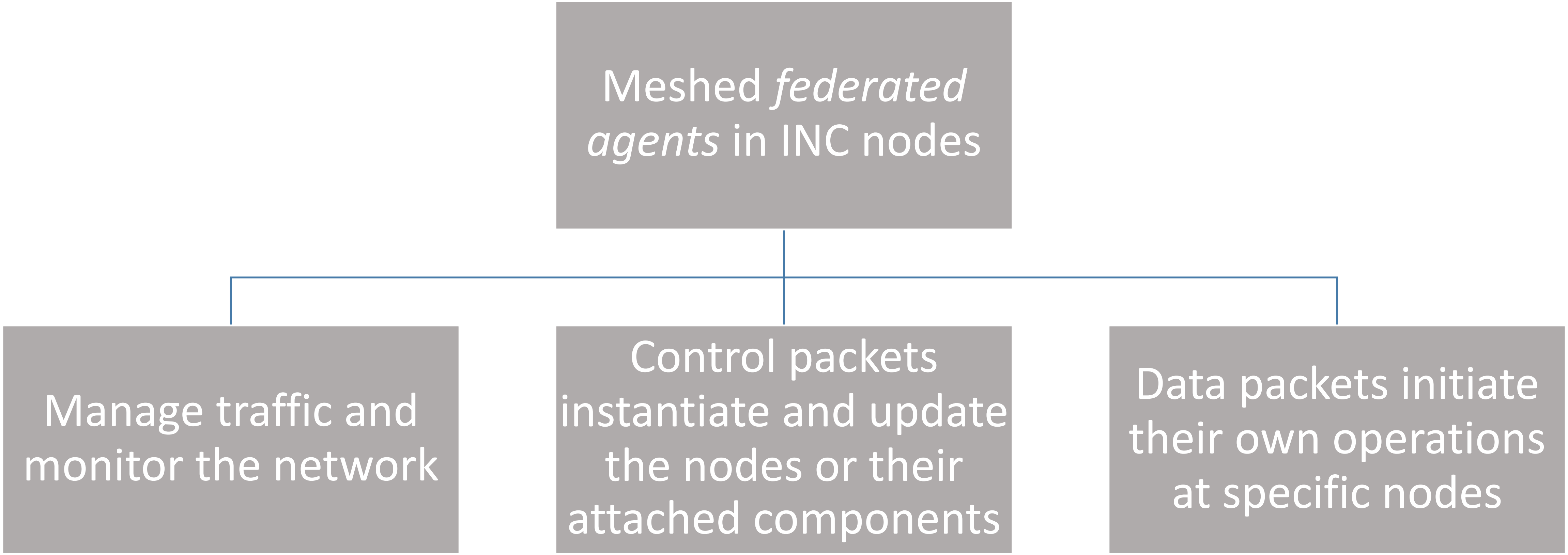


AI for 6G and 6G for AI

AI for 6G: Federated applications and networks



AI for 6G



Meshed *federated agents* in INC nodes
Manage traffic and monitor the network
Control packets instantiate and update the nodes or their attached components
Data packets initiate their own operations at specific nodes

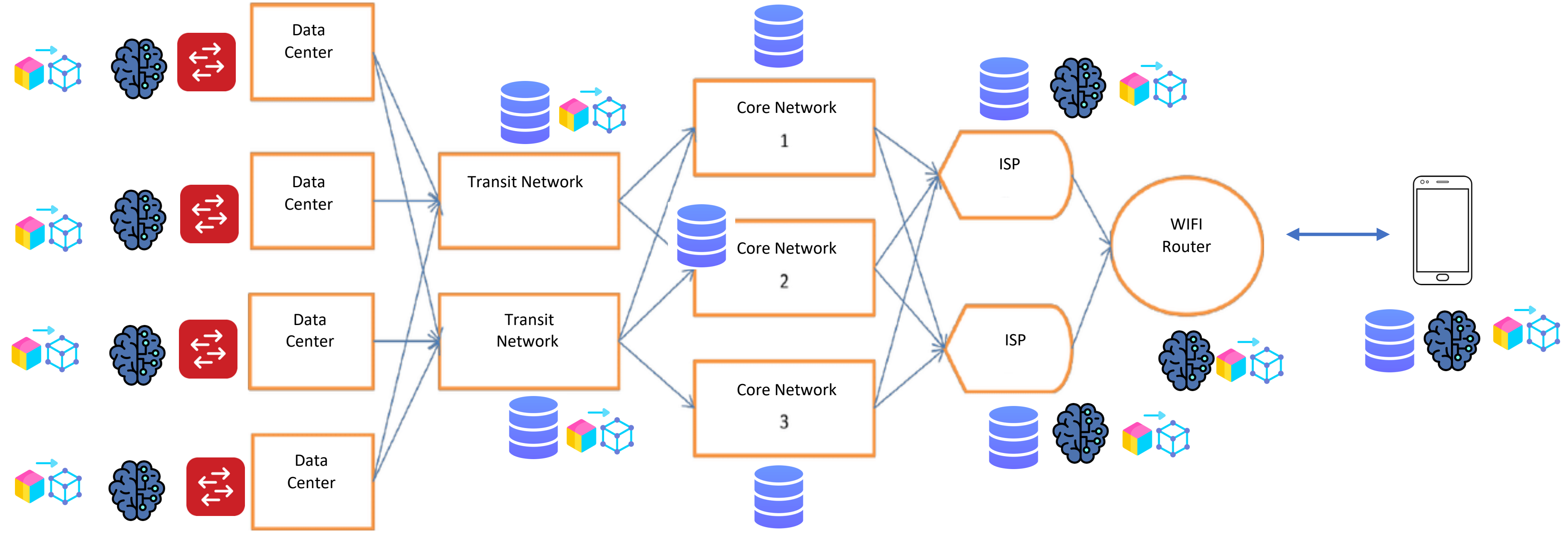
6G for AI

Multisource multi-destination data capture, storage and processing and the need for localized decision making and automation with very low delay

Support distributed decision environments, federated learning algorithms and datasets

Digital Twins in 6G Networking

- Model, simulate and test the elements of the intelligent data plane
  - Grouping several DTs into a unified one
  - World models
  - Observe and and control the behavior of the composed DT as well as the individual components
  - Applications can query and control the status of the aggregated DTs as well as the single DT



Summary: Using Intelligent Dataplanes in 6G

Self-Optimizing Networks (SONs)

- Automation and network optimization:6G mobile networks will be extremely automated
- Reduce network management costs to boost profitability

Artificial Intelligence and Machine Learning

- Anomaly detection/analytics: Instrumentation in nodes with real-time vs. long term estimates
- Digital Twins in Networking
- Programmable intelligent RANs in Wireless

Network Functions Virtualization (NFV) and Software Defined Networking (SDN)

- Meet the growing requirements for high-speed (mobile) broadband
- Merging of networking with computing and storage to added to cloud-style software
- Lower costs for network operators (OPEX/CAPEX)

6G Research topics

Joint optimization of networking, computing and application requirements in the fog/edge/cloud

Horizontalization of data plane to **enable cross functional distributed application** and cognitive intelligence linking the application and network

Secure and robust common APIs between the applications/service and infrastructure resources (application drive the network program)

Conclusion: 6G intelligent dataplanes

A programmable framework for advanced IoT and application driven networking

Fog/Edge and cloud support for advanced network services and applications based on and enabling AI/ML

Data combined with digital twinning provide targeted services and advanced testing and deployment and facilitate application development

Questions?

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