ITU's ML-aware 5G architecture Bringing Intelligence to Verticals

Navneet and Vishnu
ITU FG ML5G

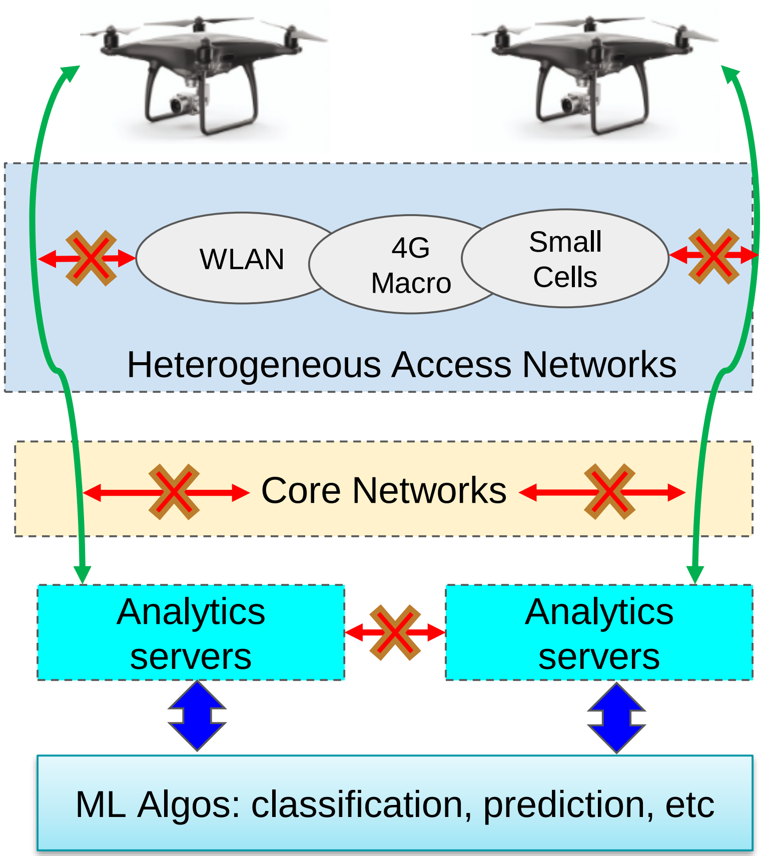
ITU ML pipeline

Use cases

Drones in e-agriculture

- Crop production: drones can do soil health scans, monitor crop health, assist in planning irrigation schedules, apply fertilizers, estimate yield data and provide valuable data for weather analysis.
- Disaster risk reduction: water stress or lack of specific nutrients in crops
- Forestry collecting various forest metrics such as carbon sequestration, tree canopy analysis, conservation features, tracking native species, monitoring biodiversity and ecological landscape features.
- Data collected through drones **combined** with other data sources and analytic solutions provide actionable information.

Ref: https://www.itu.int/dms_pub/itu-d/opb/str/D-STR-E_AGRICULT.02-2018-PDF-E.pdf


WLAN
4G Macro
Small Cells
Heterogeneous Access Networks
Core Networks
Analytics servers
Analytics servers
ML Algos: classification, prediction, etc

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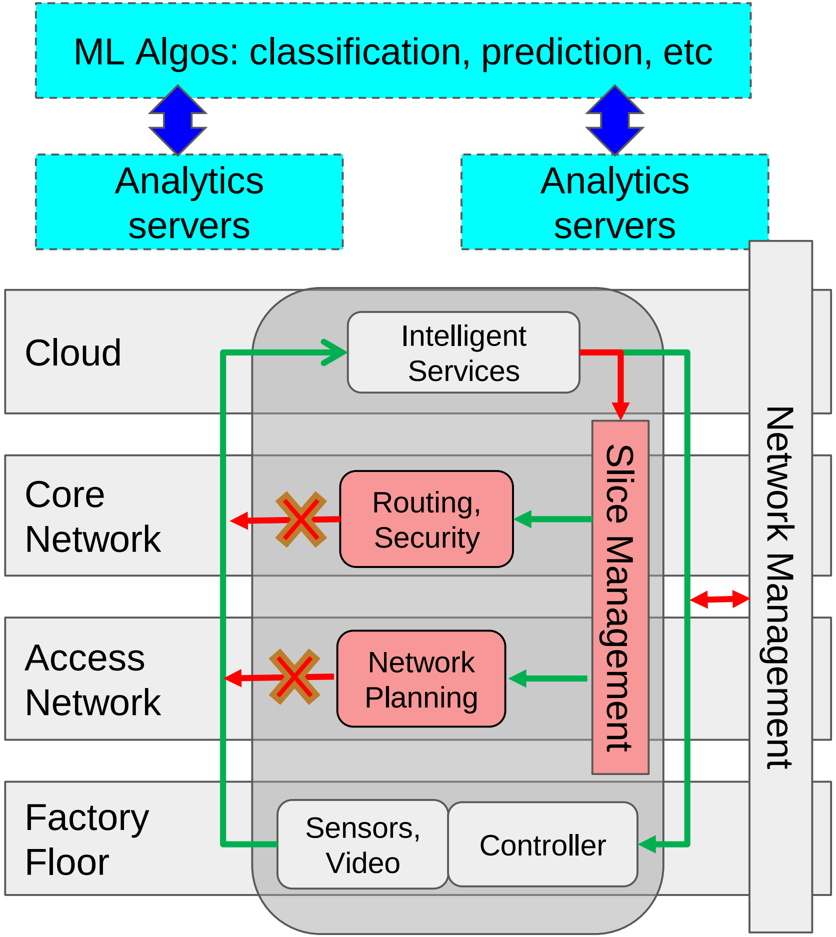
Use cases (e-Factory)

- Factory floor: Tracking and control using local and cloud based services
- Possible sources of data: Equipment sensors, Radio maps, MIMO CSI, etc.
- Possible sinks: Equipment controller, Network elements at different levels.

Edge and cloud based use-case scenarios:

- Failure predictions and preventive maintenance
- Network reconfiguration
- Incremental model updates at edge
- Intelligent robot arms



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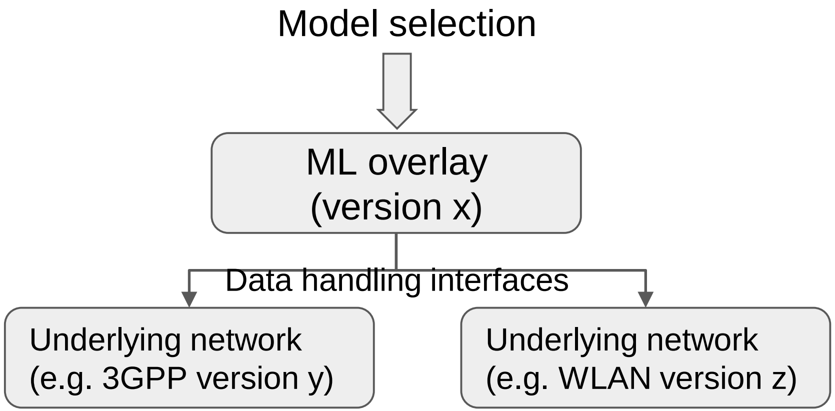
Architecture approaches (1/4)

- ML mechanisms must evolve independent of underlying networks. (x ≠ y ≠ z)
- ML must plug-in using a standard framework
- ML mechanism should be solving the problem, selection of ML mechanism should use the description of the use case.



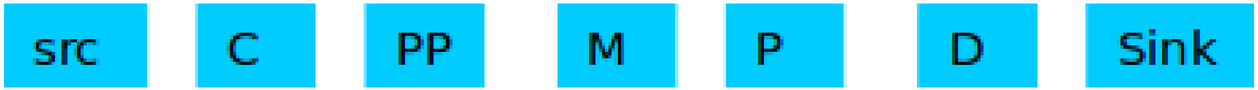
Model selection

ML overlay (version x)

Data handling interfaces

Underlying network (e.g. 3GPP version y)

Underlying network (e.g. WLAN version z)



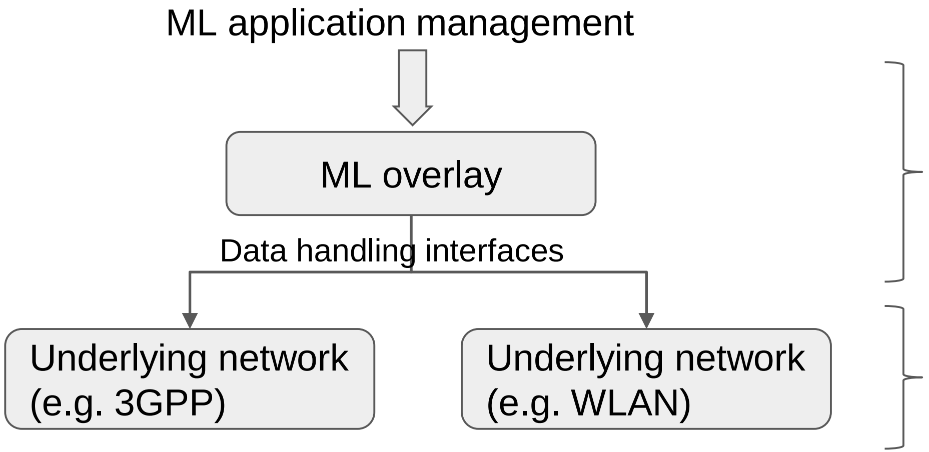
src C PP M P D Sink

Architecture approaches (2/4)

ML overlay

- Enables interoperability of ML applications with heterogeneous underlying networks (e.g. 3GPP or WLAN, verticals)

- Allows rapid provisioning of ML applications


ML application management
ML overlay
Data handling interfaces
Underlying network (e.g. 3GPP)
Underlying network (e.g. WLAN)

Define a common vocabulary and nomenclature for ML functions and their interfaces.

By applying (or superimposing) this logical architecture to a specific technology, like 3GPP, MEC, EdgeX or transport networks, the corresponding technology-specific realization is derived.

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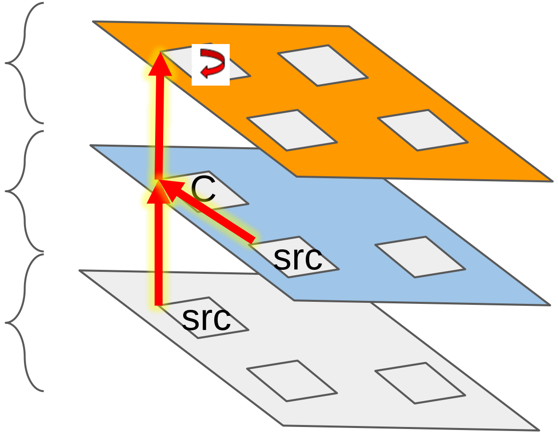
Architecture approaches (3/4)

- Allows chaining of ML pipeline functions.
- Inter-domain, standard interface which include chaining.
- between ML mechanisms hosted in different domains (e.g. Edge, Core, RAN, WiFi AP)

Level-3: e.g. Application functions (hosts a model)

Level-2: e.g. CN (hosts another src)

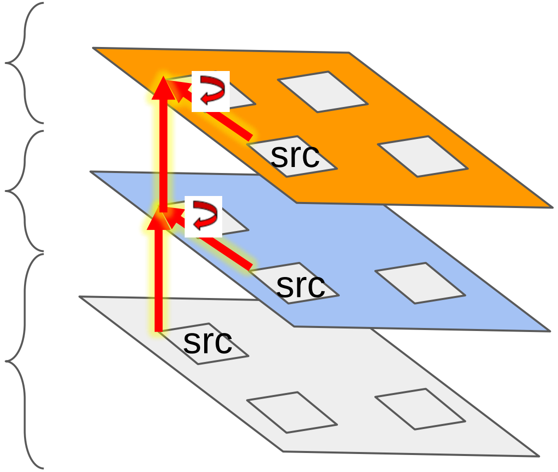
Level-1: e.g. RAN (hosts a src here)



Level-3: Hosts another model (chained)

Level-2: hosts another model (chained)

Level-1: e.g. RAN (hosts a src here)



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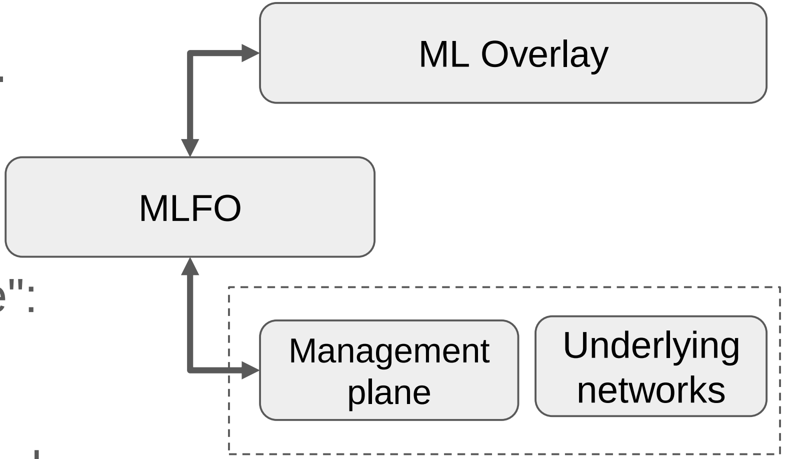
Architecture approaches (4/4)

Automation, adaptation, monitoring:

1. Done by orchestrators for IMT 2020 NFs.
2. Similar function needed for ML pipeline nodes.
3. MLFO functions as the Middle-man between Platform, Infra, Software, and ML.
4. Manages a simulator+trial-sandbox.
5. Agnostic but "opportunistically-resource-aware": e.g. Resource status, scaling decisions, accelerator availability.
6. Effect of ML on the network has to be monitored for impacts on E2E service.



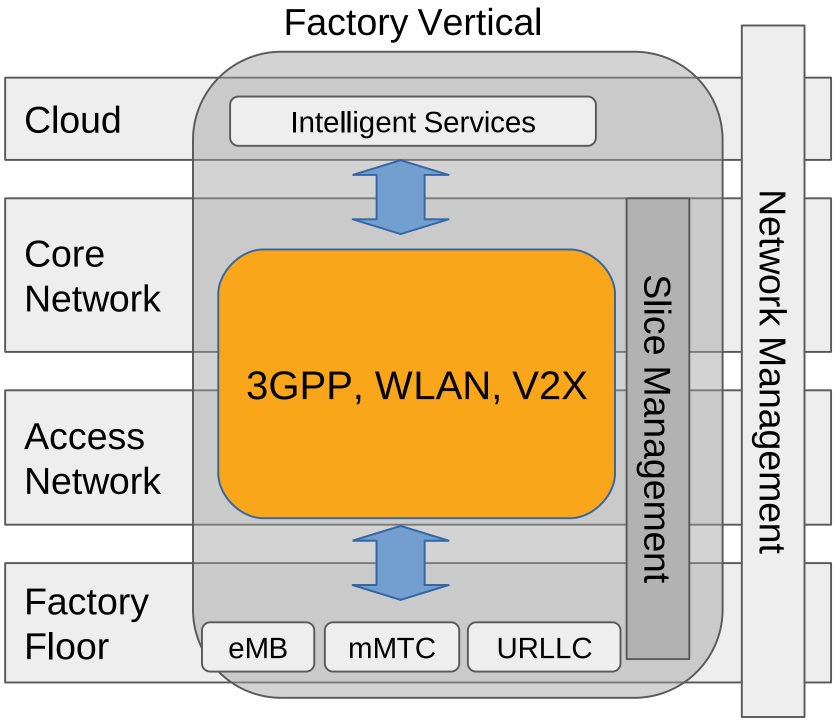
Realization example: e-Factory

Factory Automation : Tracking and Control

- **Input:** Sensors (position, speed), CSI, Traffic routes
- **Output**: Robots (tracking, control), Network planning
- **Computing:** Edge and/or Cloud
- **Real-time feedback:** Control of devices

Anticipated features

- **ML-aware –** Orchestration of ML functions over network
- **Technology agnostic** - 3GPP, ETSI, IEEE, etc.
- **Heterogeneous ecosystem** - URLLC, mMTC, eMB
- **Deployment and management ecosystem** – MLFO



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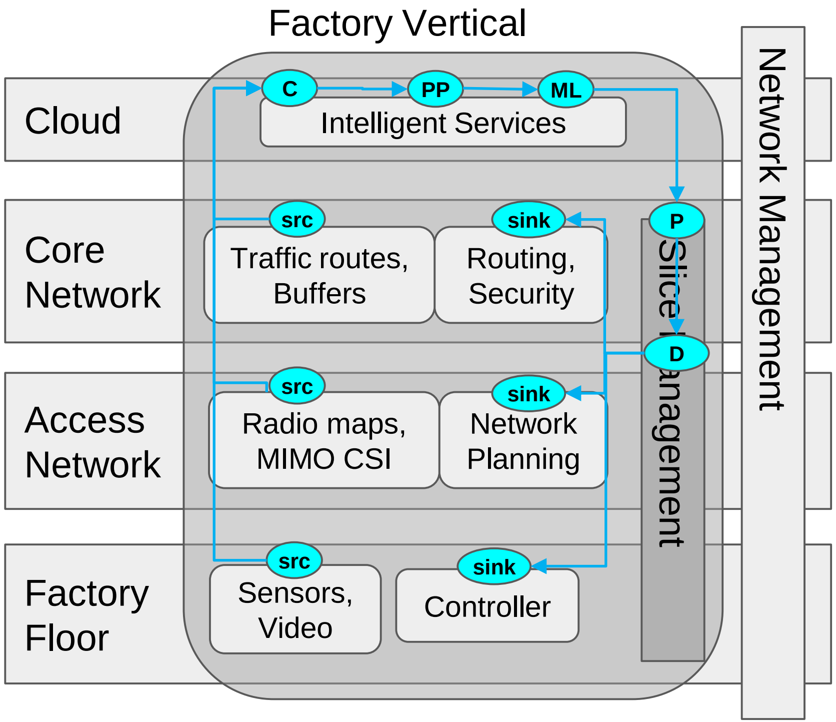


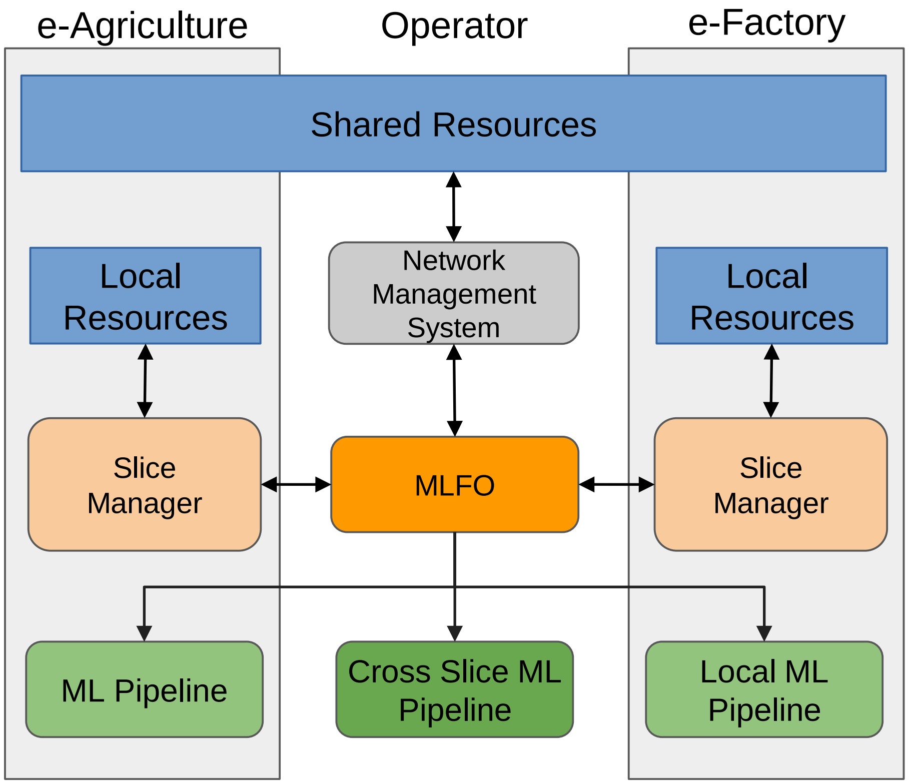
Vertical-Operator Interplay

Verticals:

- **Deploy** of ML services over the Network Slice
- **Monitor** and **Configure** parts of underlying network
- **Optimize** resources for achieving QoE required

Network Operator:

- Enable **easy configuration** for clients (Verticals)
- **Technology agnostic** network monitoring and control
- **Common platform** for all ML based services
- **Secure** flow of data across slices and/or domains
- Deploy ML Pipeline **across multiple slices**



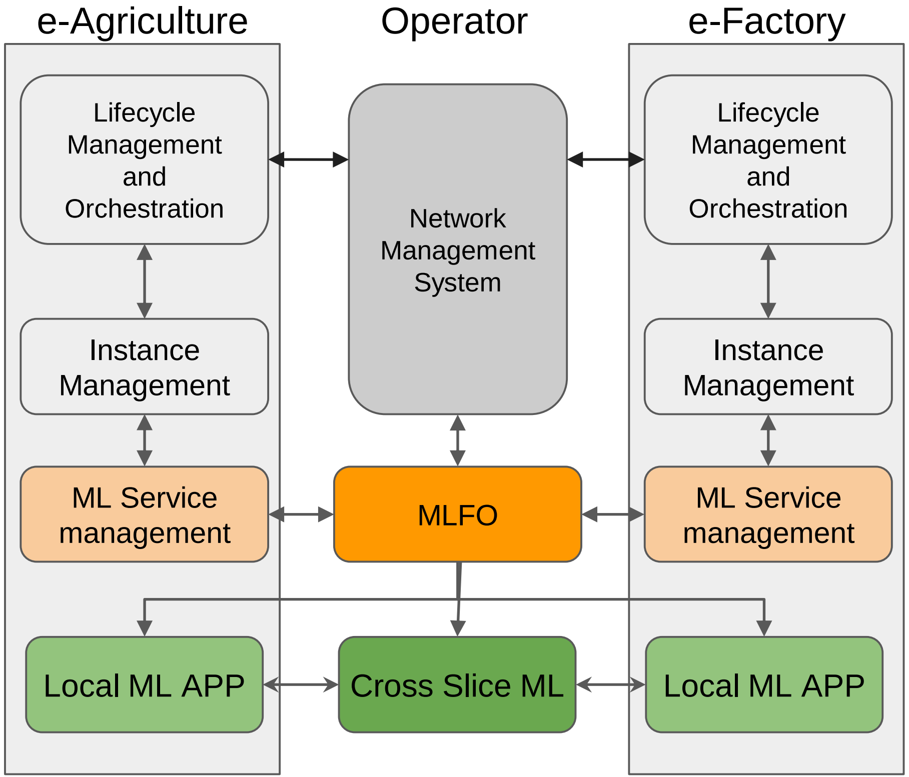
M for Management

Network Slice Management

- Local ML Pipeline instantiated and managed through **common MLFO platform**
- Management of resources across multiple slices facilitated by **Cross-Slice ML Pipeline**

Machine Learning Function Orchestrator (MLFO)

- Extend NFVO to incorporate ML Pipeline
- **Ecosystem** for deployment and management of ML applications
- **Cross-layer Cross-Slice** management and deplyoment



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Data handling

Logical ML Pipeline

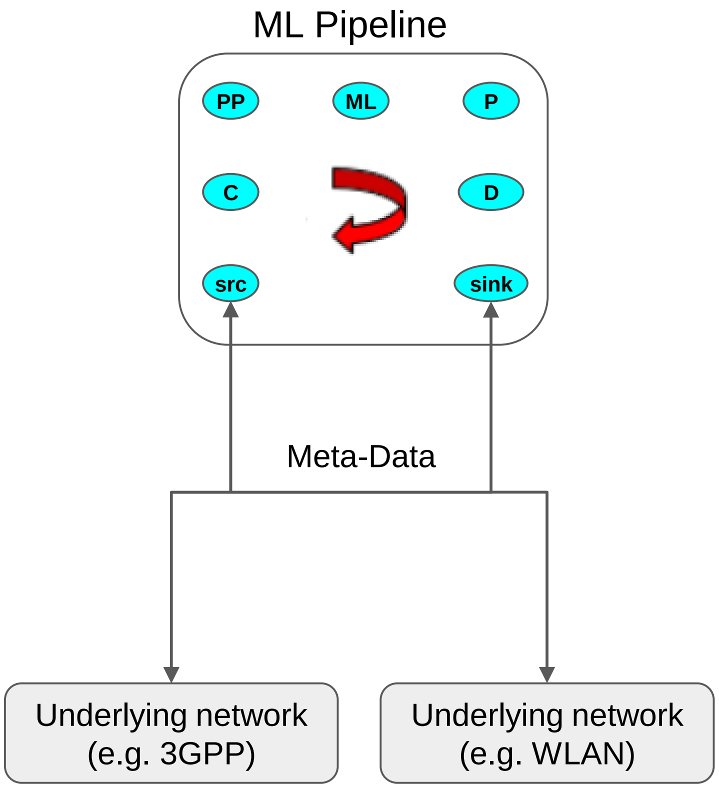
- Only Src and Sink depends on specific ML Service
- **Interoperability** with different technologies
- Universal **meta-language** for MLFO

Data Formats and Interfaces

- Data I/O format **independent** of technology
- **Technology specific interfaces**

Data Exposure and Preprocessing

- **Exposure** of relevant data to stakeholders
- **Feature extraction** from multiple sources
- **Continuity and Integrity** of available data
- **Simulation data** for training and model update


ML Pipeline
PP
ML
P
C
D
src
sink
Meta-Data
Underlying network (e.g. 3GPP)
Underlying network (e.g. WLAN)

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Sandbox

Characteristic Features:

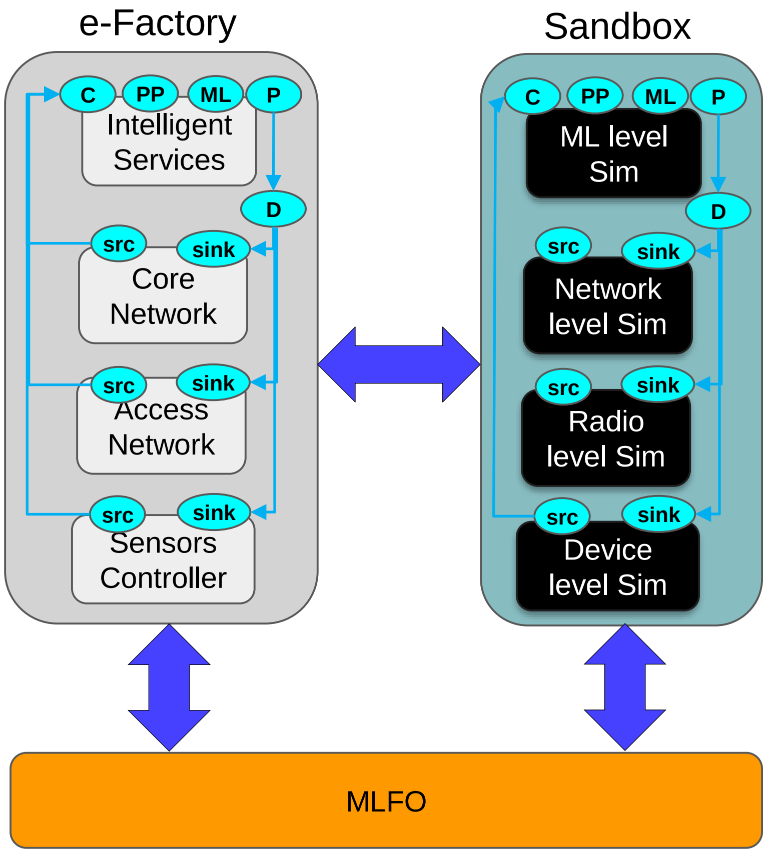
- Evaluate and update ML techniques before deployment using real and simulated data
- Driven by Simulators complemented with Real data
- Parallel real-time monitoring and update

Enablers:

- Standard interfaces
- Exploits multi-level architecture of ML-Pipeline
- Management capabilities for MLFO
- Model-Model interface for chaining

Network Slice Sandbox

- Slice level simulation modeling



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Advantages and the Stakeholders

Advantages of the ML-Pipeline based Architecture

- Specify the ML application using **logical nodes** and deploy on any underlay with the help of **MLFO**
- Monitor, manage and optimize using **sandbox**
- **Cross-layer** architecture using MLP

Verticals:

- **Orchestration and management** via common platform and universal language

Operators:

- **Specifically tailored** solution for ML services and **Intelligent resource management** across Slices

Researchers:

- Provides common framework for **developing and testing new algorithms**
- New research opportunities in developing **MLFO**

Future work: Call for contributions!

tsbfgml5g@itu.int

- ML5G-I-126R4
    - Proposal for future work plan
    - WG1: Gap analysis & applications of MLP for verticals.
    - WG2: Recommendations for Data handling, intelligence levels
    - WG3: Recommendations for MLFO interfaces, Intent definitions, sandbox+training mechanisms
- ML5G-I-118-R9
    - Use cases.
- ML5G-I-121-R3
    - Intelligence levels.
- SG13-TD314/WP1
    - Architecture framework

Student Summer Projects!!!