Balancing Uneven Knowledge of Hospital Nodes for ICU Patients Diagnosis through Federated Learning

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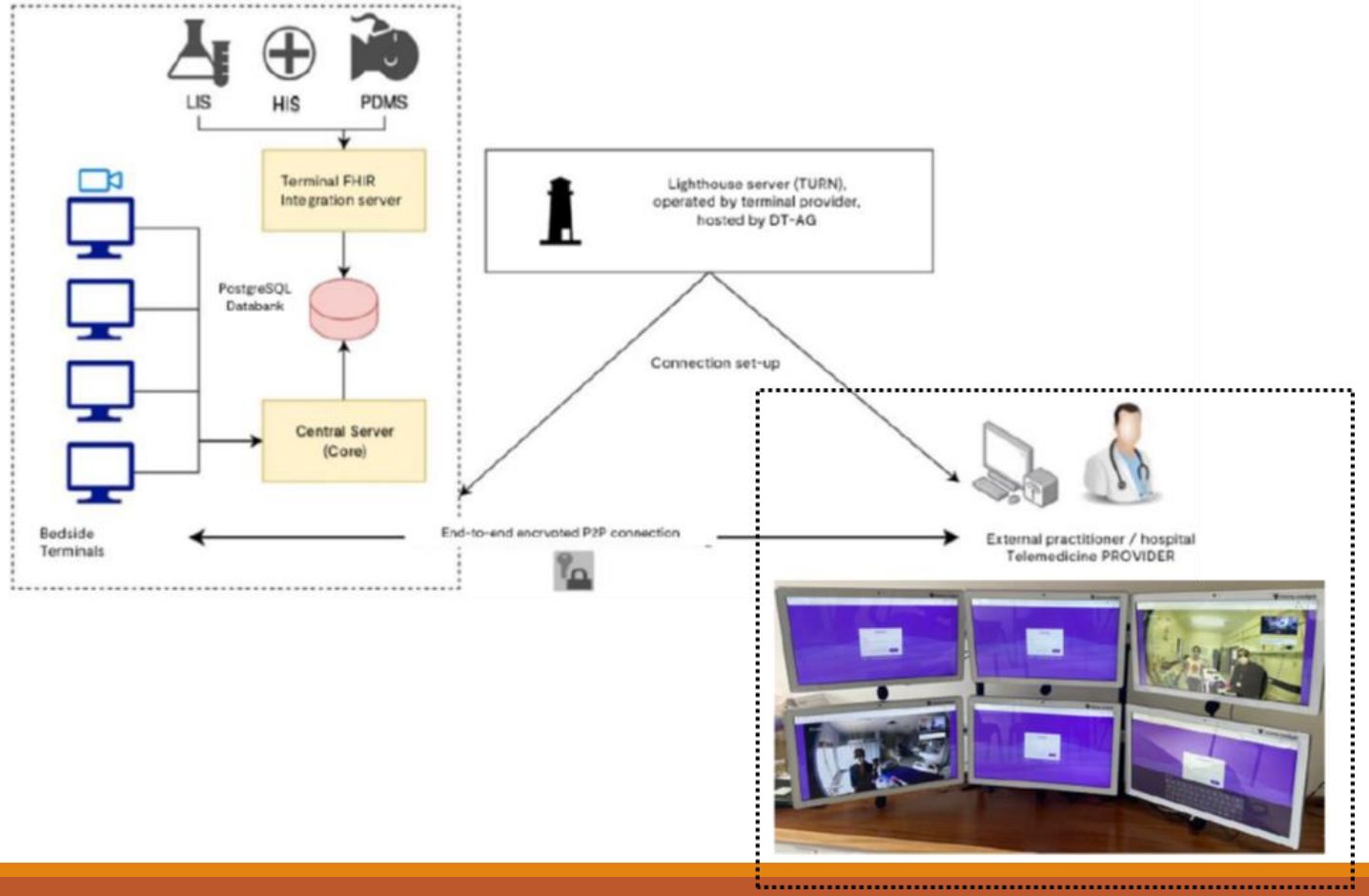
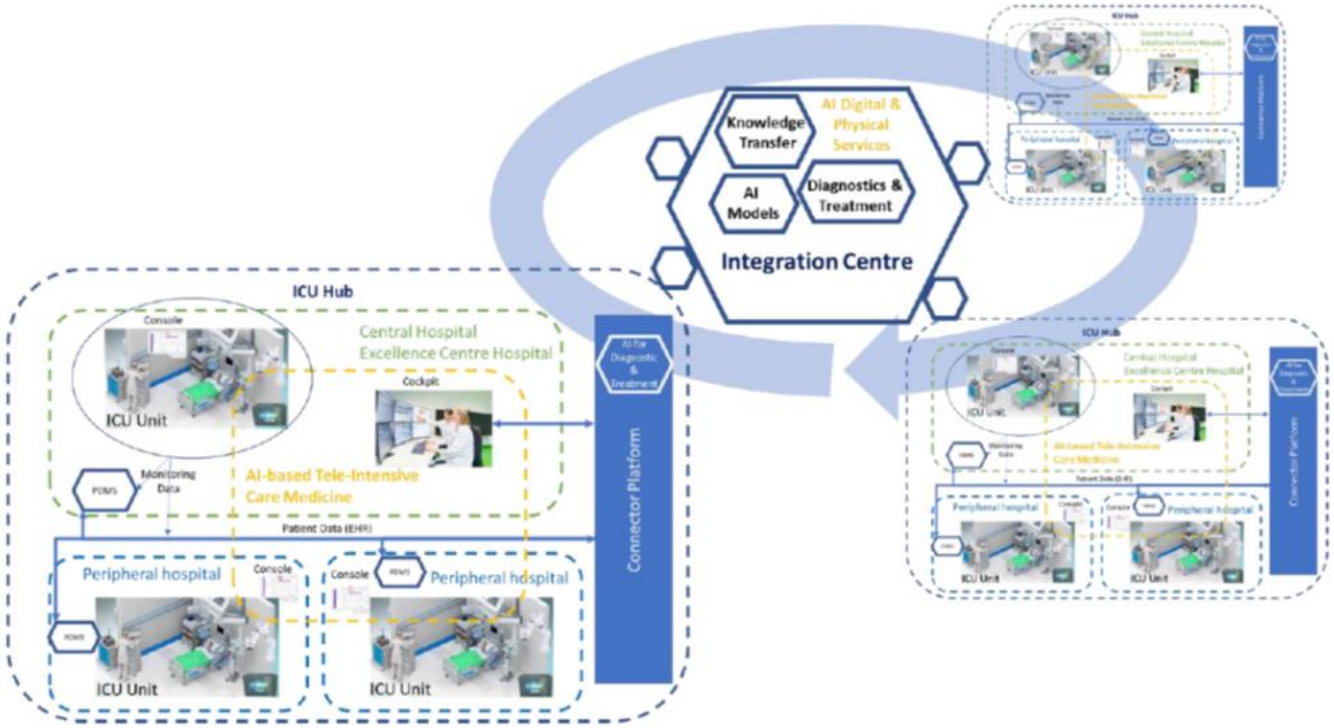
Context of the Research Activities

- The SARS-CoV-2 pandemic highlights the need to improve cooperation and knowledge sharing to prevent disease spread and ensure quality patient care.
  - uneven distribution of capacities and resources between healthcare organizations situated in small centers and those in urban areas makes it difficult to provide the same quality of healthcare services
- The **ICU4Covid** project aims to create a European telemedicine network composed of a set of independent Cyber-Physical Systems for Telemedicine and Intensive Care.



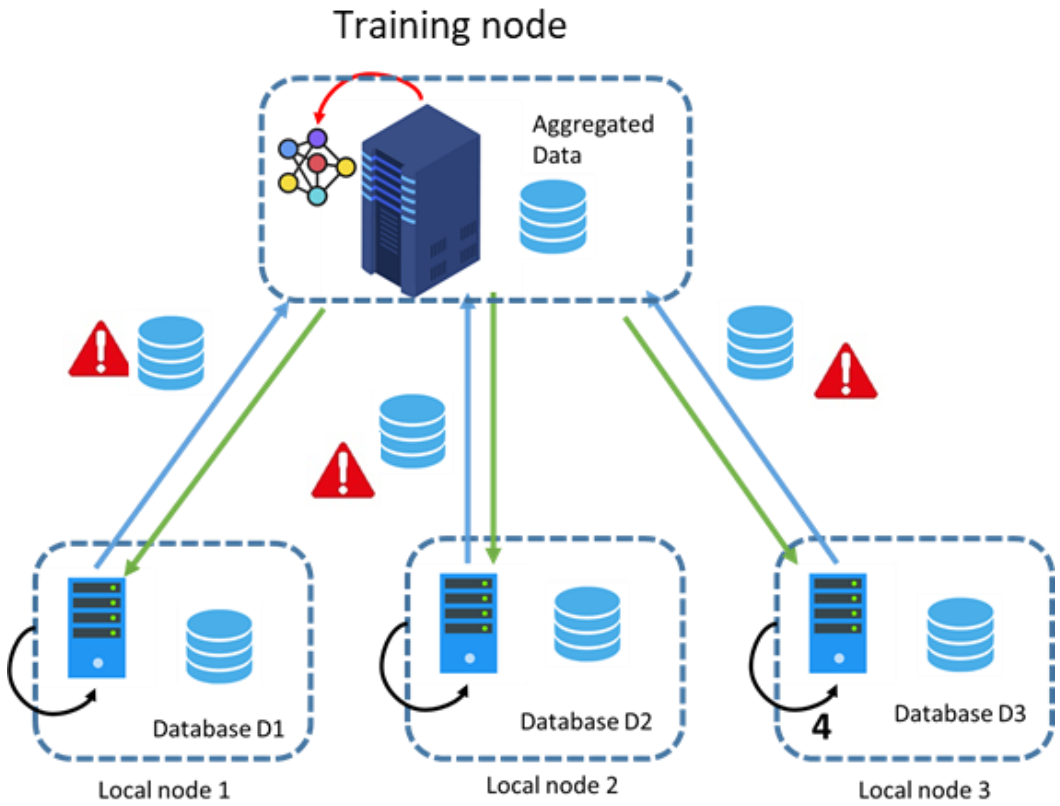
Cyber-Physical Systems for Telemedicine and Intensive Care Architecture (CPS4TIC)

- A **network of research institutions, medical centers**, and hospitals all around Europe join under the umbrella of the ICU4Covid project.
- Each ICU Units equips with state-of-the-art technology, such as a 5G module, radar sensors, and **AI chips.**
  - Integrates health-related data
  - Collects and integrates real-time health-related data from wearables, sensors, and smart devices
  - **Deploy an AI-based decision system to support doctors and nurses with precise decisions, evidence-based treatment, and efficient use of time resources.**



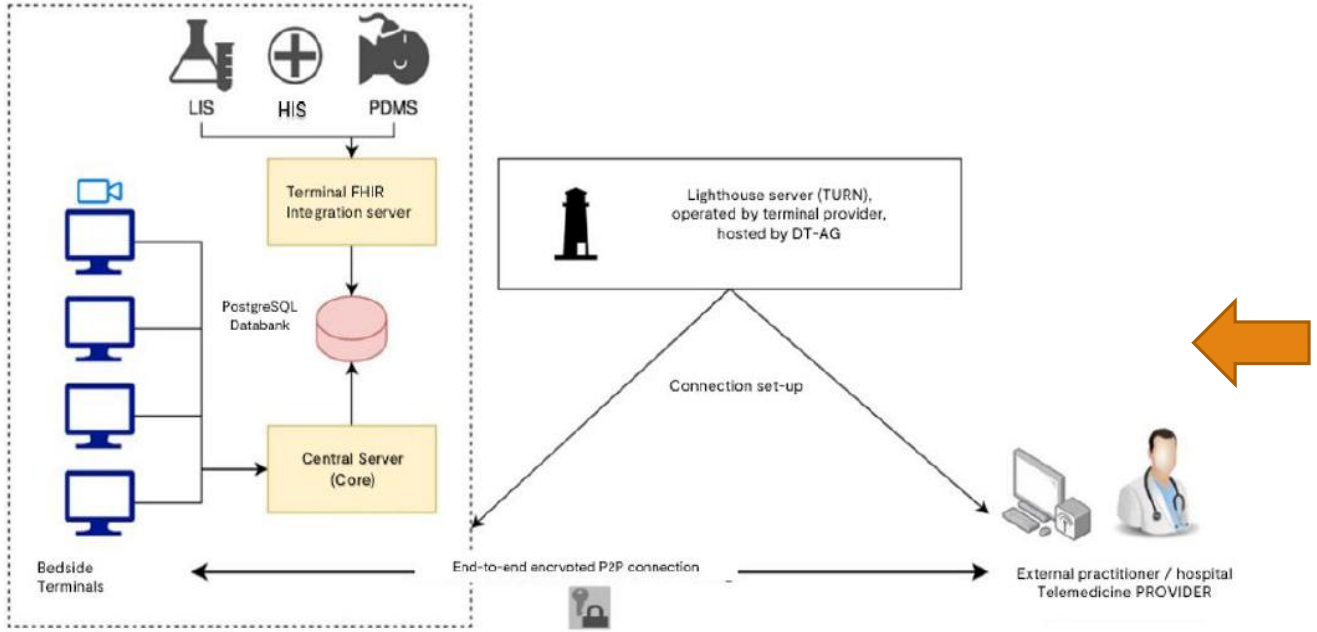
Learning in Distributed Environments

- Problem
  - Traditional learning approaches are centralized
    - Need to move data from sources to a training node
      - **Privacy and Security Issues**
- Federated Learning to handle these issues
  - Definition of a federated learning approach for the training of a time series (TS)-based model for the early identification of both high-risk and low-risk hypertensive patients in a **federated** environment
- Move Local Model instead of Data
  - **NO Privacy and Security Issues**

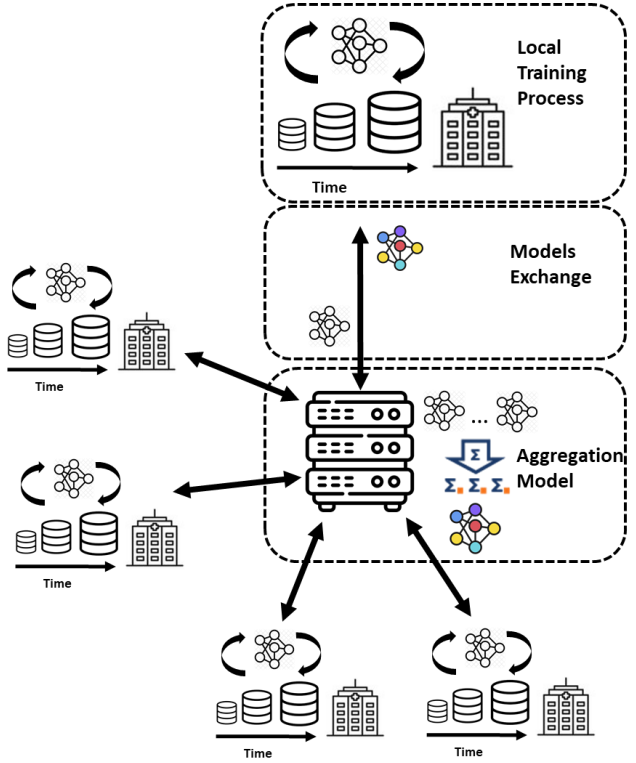


CPS4TIC enhanced with Federated learning

- Integration between CPS4TIC and a federated learning architecture
  1. Integrate a federated client in each Mona node
  2. End-to-end P2P encryption to communicate with an aggregator server
  3. Definition of a global model to assist health professionals in the best patient treatment



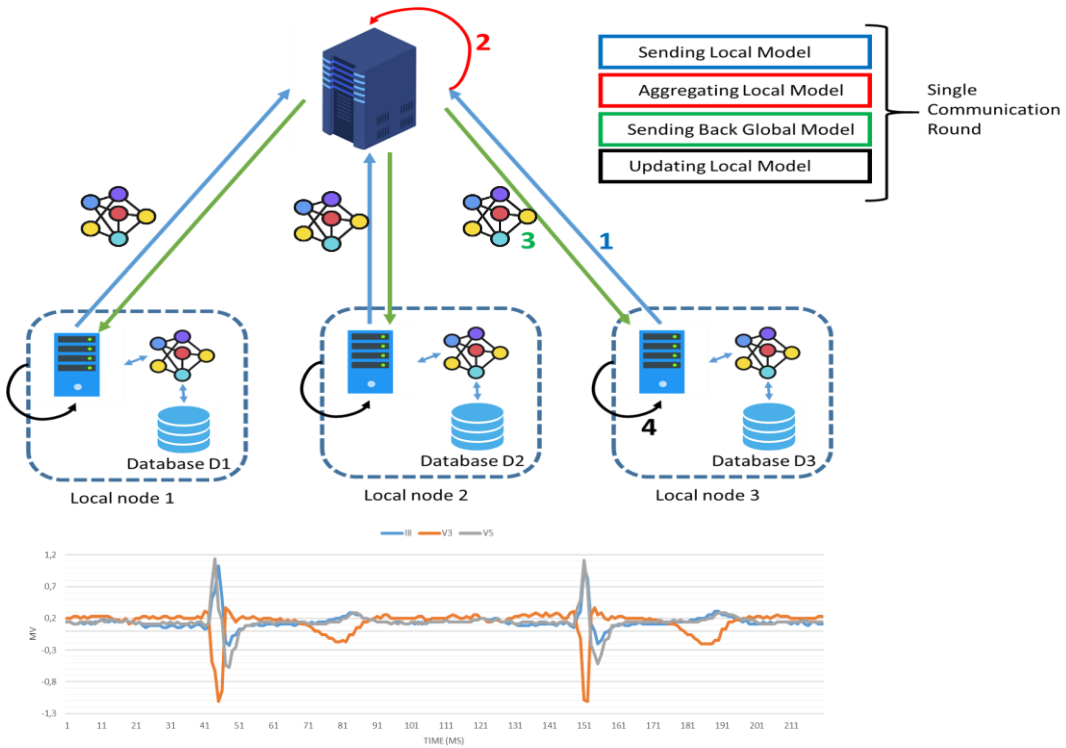
CPS4TIC Full System



Client/Server Federated Architecute

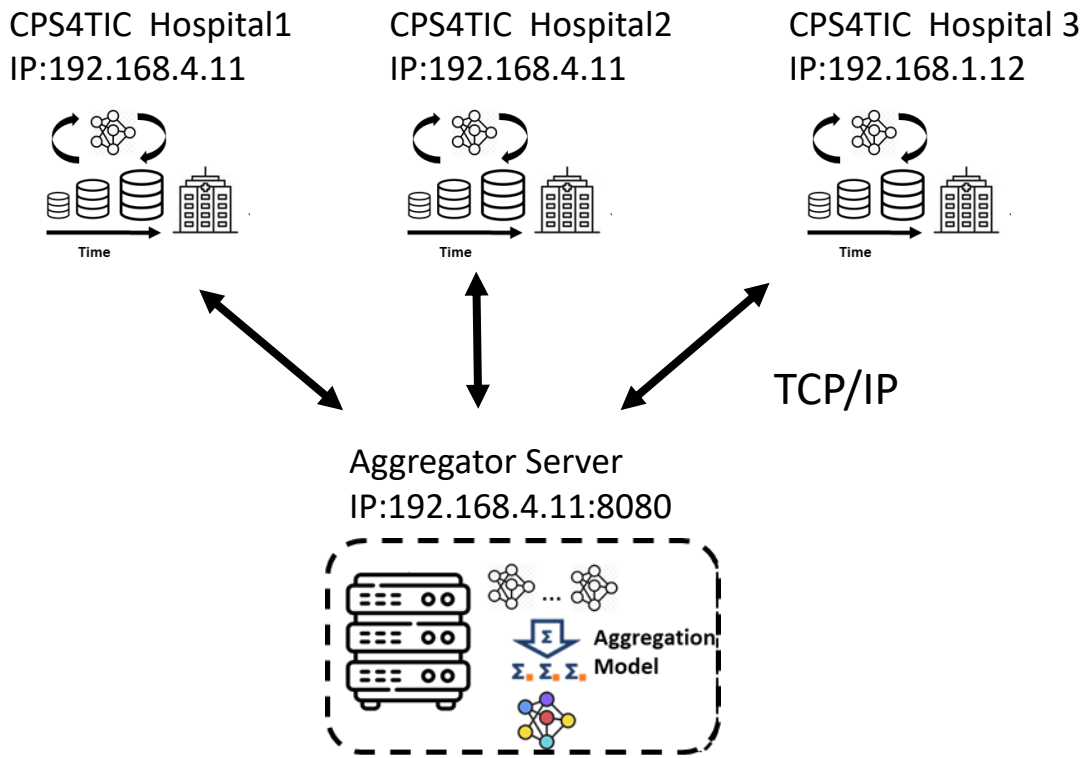
Evaluation of the Federated Architecture – Use Case Scenario

- Application of Federated Learning approaches in healthcare domain to support monitoring and telemedicine systems
  - Data
    - Biomedical Signal - Electrocardiographic (ECG) - Holter recordings
    - **Training dataset**
      - Open Data (Physionet.net Repository)
      - Distributed among different nodes
  - Federated Configuration
    - 3 clients
    - 1 Server Aggregator
    - Same network in each node
    - Hybrid Network: CNN + LSTM + DMM
  - Results
    - Federated performance results comparable to the centralized



Federated Architecture Validation

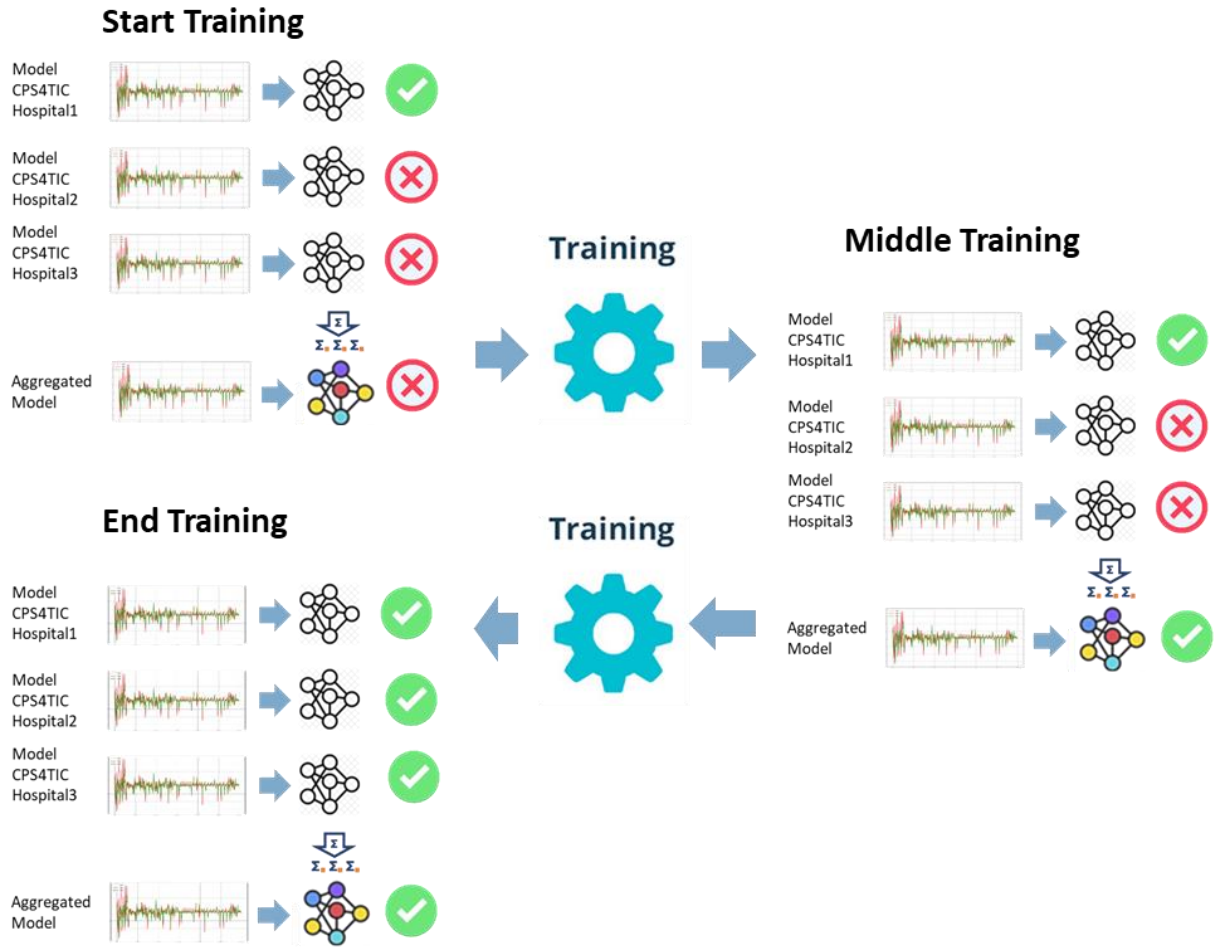
1. Initialize all nodes involved in the learning process
   - Initialize Aggregator server and CPS4TIC system on node1 and node 2
   - Initialize CPS4TIC system on node3
2. After the initialization, make each CPS4TIC node running
   1. Running CPS4TIC systems on node 1 and node2
   2. Running CPS4TIC system on node 3
3. After each node gets running, the learning process starts
   - Aggregator Server waits for the models. The aggregation process will start when the server receives all three CPS4TIS local models.
   - Learning on CPS4TIC systems on node 1 and node2
   - Learning on CPS4TIC system on node 3
   - When the server collects all models, the aggregation starts
4. Step 3 is repeated more times until the end of the training process



Results Validation 1/2 - Local Models VS Global Model

Collection and Comparison between the local models and the global model

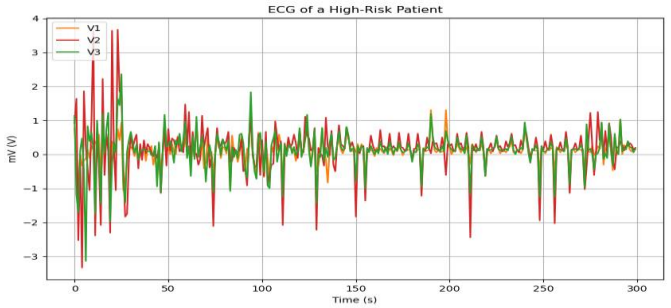
Test Set	LocalModelVS Global Model	Accuracy	Winner
1	LocalModel 1 VS Global Model	LM = 0.67 GM=0.86	Global Model
2	LocalModel 2 VS Global Model	LM=0.74 GM=0.89	Global Model
3	LocalModel 3 VS Global Model	LM=0.59 GM=0.93	Global Model



Results Validation 2/2 - Test Validation

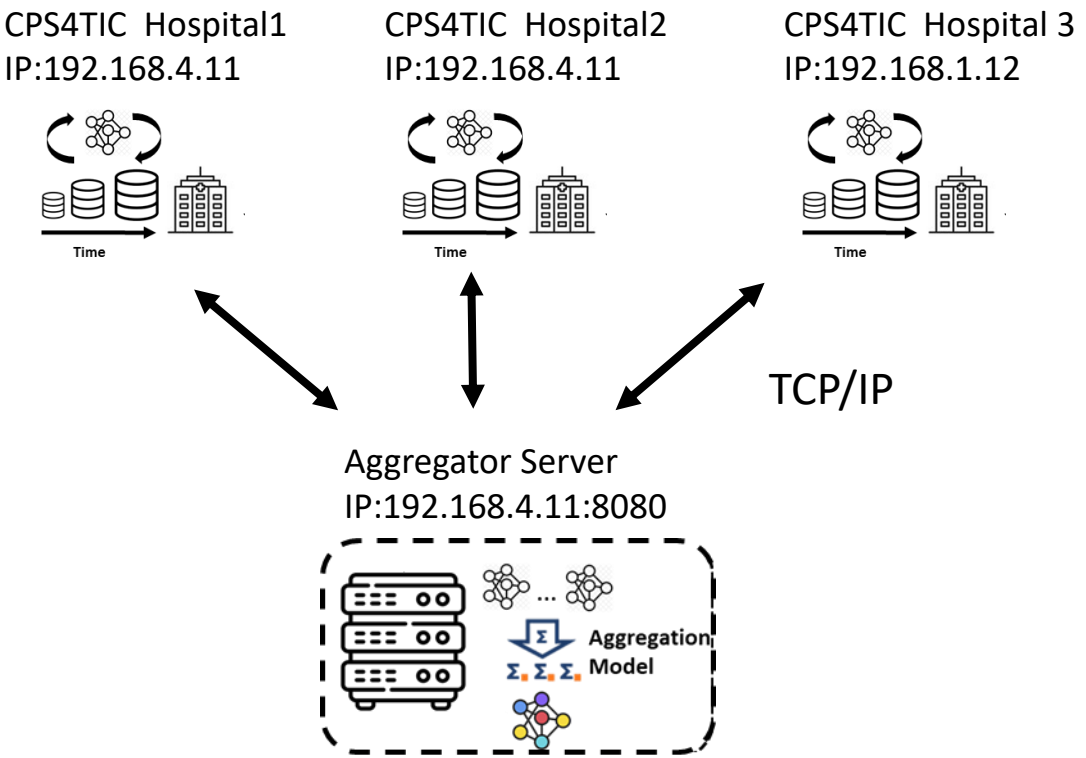
Prediction Test

- Take an ECG sample from CPS4TIC Hospital1 following the research activities d conducted by CNR



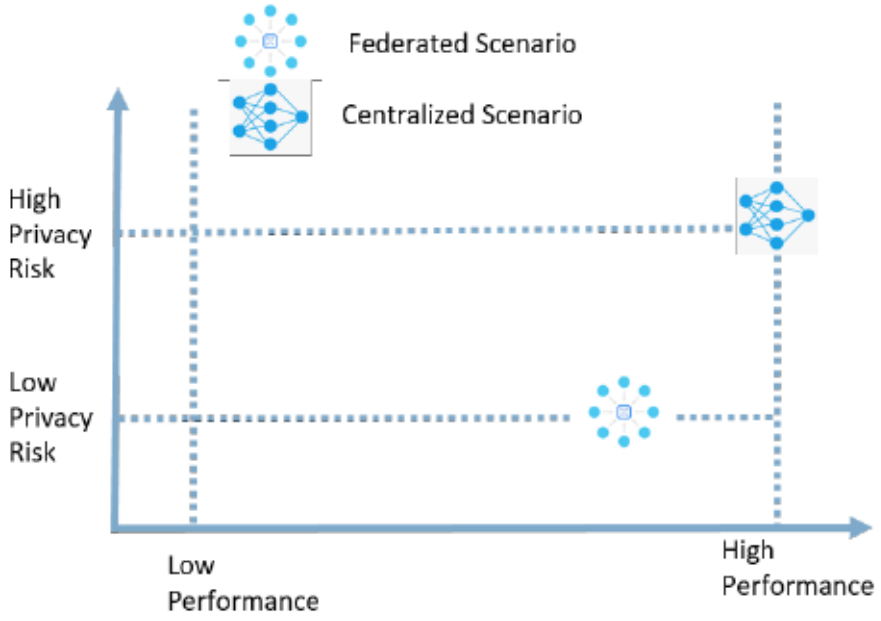
- Predict CPS4TIC Hospital2 model
- Predict the global model

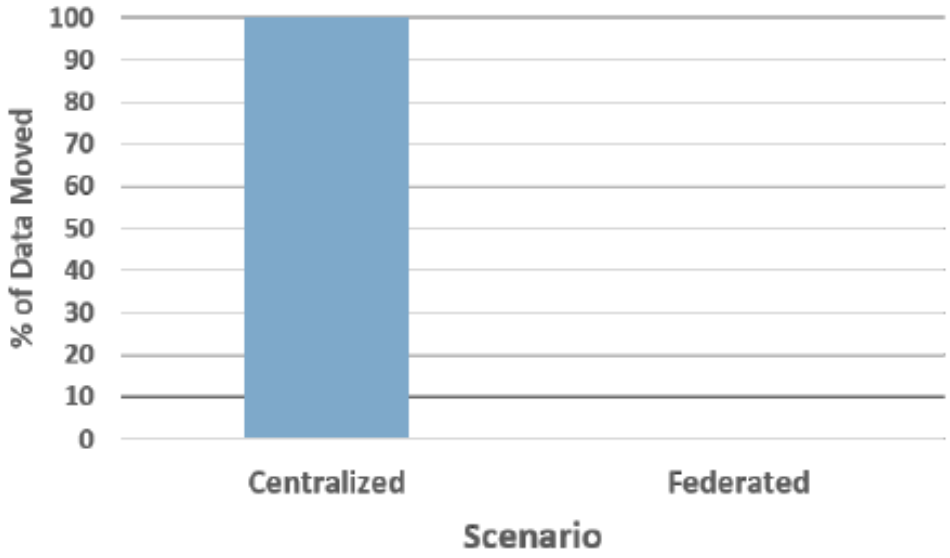
True Value	CPS4TIC Hospital2 model	Global Model
High	Low	High



Conclusions

- The centralized mode will require moving all data from its stored nodes to the node performing the learning process. Thus, data security and privacy are compromised by this action.
- The federated approach prevents privacy risks since no data are moved; only the federated model parameters are transferred.





Approach	Accuracy	Precision
Federated Scenario	0.90+-0.0019	0.91+-0.0059
Centralised Scenario	0.98+-0.005	0.98+-0.002

QUESTIONS?

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