
Join us for the
2022 NephroCAGE Symposium
Aug 16, 2022 @ 6.15 am PDT / 9.15 am EDT / 3.15pm CEST
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NEPHROCAGE
German-Canadian consortium on AI for improved kidney transplantation outcome
2nd International NephroCAGE Symposium, Aug 16, 2022
Hasso Plattner Institut
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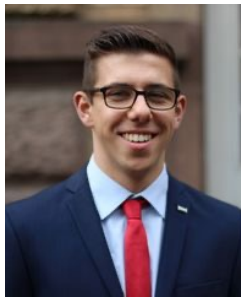
KIT project team

M. Sc. Florian Leiser



- Research associate at the KIT since 2021
- M.Sc. in information systems in 2021
- Research interests: health information systems, informed ML, federated learning

M. Sc. Konstantin Pandl

- Research associate at KIT since 2019
- M. Sc. in electrical engineering and information technology in 2018
- Research interests: machine learning, digital health, distributed systems

Dr. Scott Thiebes

- Research associate with Prof. Sunyaev since 2014
- Research interests: digital transformation, information privacy and critical digital health infrastructures, trustworthy AI, persuasive digital health technologies

Prof. Dr. Ali Sunyaev

- Professor at KIT and director of the AIFB since 2018
- Previous professorships at the University of Cologne and Kassel
- Research interests: trustworthy artificial intelligence, innovative health IT solutions

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Goals of the work package

Design a **federated learning infrastructure**

1

Develop this infrastructure and **deploy** it at each site

2

Evaluate the infrastructure's utility

3

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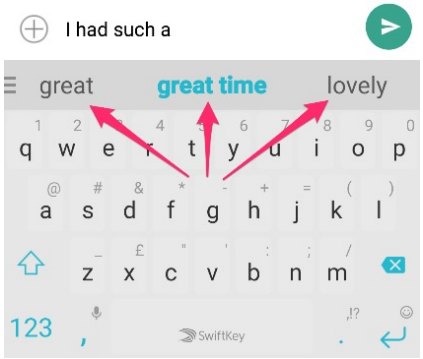
History of federated learning

- Introduced by Google in 2017
- **Initial use case:** high-quality, machine learning (ML)-based word suggestions for the Android keyboard



- **Problem:** ML process typically runs on a large data set in the cloud, but keyboard inputs are too sensitive to share them with a cloud server
- **Solution:** federated learning

Image: https://askubuntu.com/questions/1125541/word-prediction-like-android-keyboard

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Functional principle of federated learning

- **Goal:** ML across private data silos
- **Key idea:** train ML models on local data and only exchange ML models
- Process consists of repeated rounds; each round comprises 4 steps
- Central model update through averaging the local model parameters

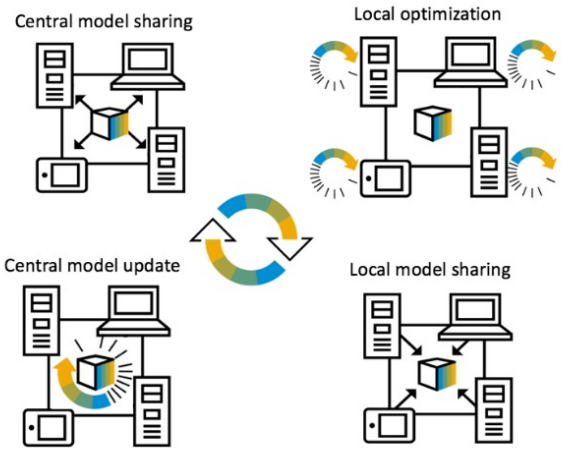
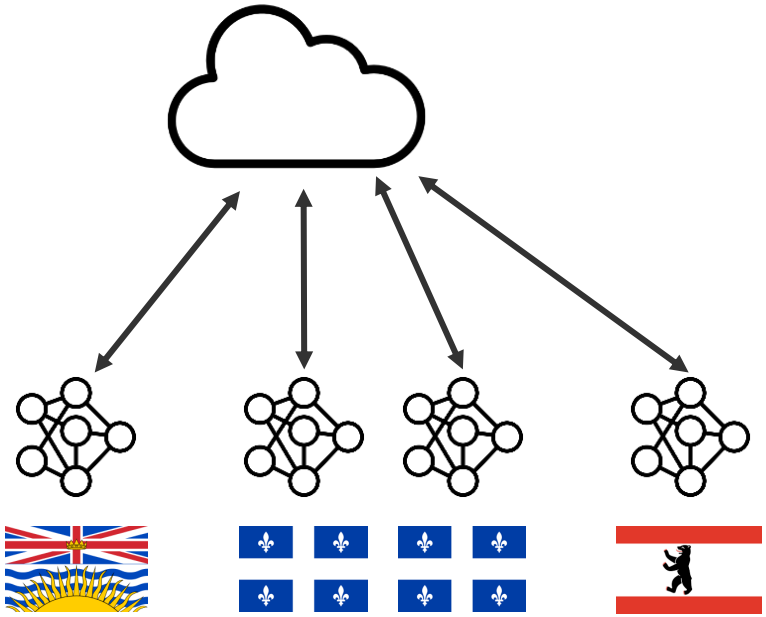
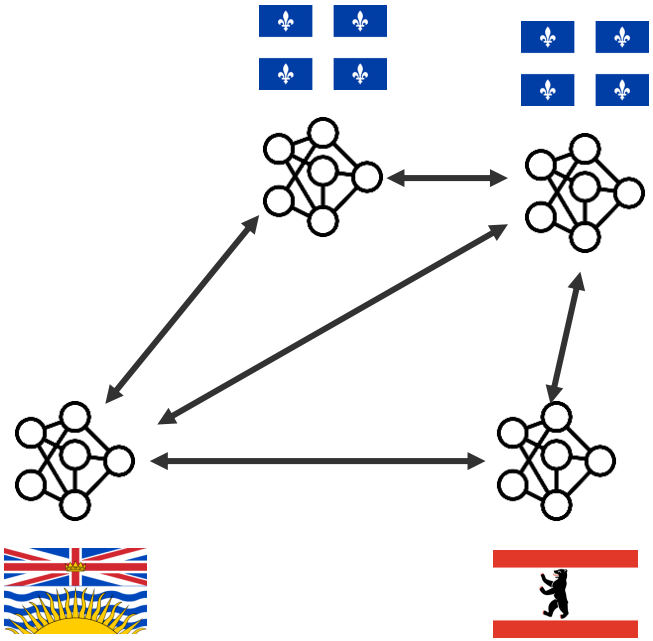


Image: https://medium.com/sap-machine-learning-research/client-sided-differential-privacy-preserving-federated-learning-1fab5242d31b

Centralized and Decentralized Learning Infrastructure





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Centralized: each clinic server communicates with a single cloud server to exchange data

Decentralized: each clinic communicates with other clinics to exchange data

Icons from flaticon.com

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Collaborative learning principles

- **Federated learning**: local optimization, then sharing updates, then aggregation, then distribution to every node
- **Braintorrent**: Local optimization, then sharing of local updates with global node, then aggregation, no redistribution [1]
- **Institutional incremental learning**: One node optimizes, then shares with one other node which re-optimizes the model [2, 3]

- Due to the challenging aggregation of random forests, we started with developing and deploying **institutional incremental learning**

1. Roy, A.G., et al., *Braintorrent: A peer-to-peer environment for decentralized federated learning.* arXiv preprint arXiv:1905.06731, 2019.
2. Sheller, M.J., et al. *Multi-institutional deep learning modeling without sharing patient data: A feasibility study on brain tumor segmentation*. in *International MICCAI Brainlesion Workshop*. 2018. Springer.
3. Sheller, M. J., Edwards, B., Reina, G. A., Martin, J., Pati, S., Kotrotsou, A., ... & Bakas, S. (2020). Federated learning in medicine: facilitating multi-institutional collaborations without sharing patient data. *Scientific reports*, *10*(1), 1-12.

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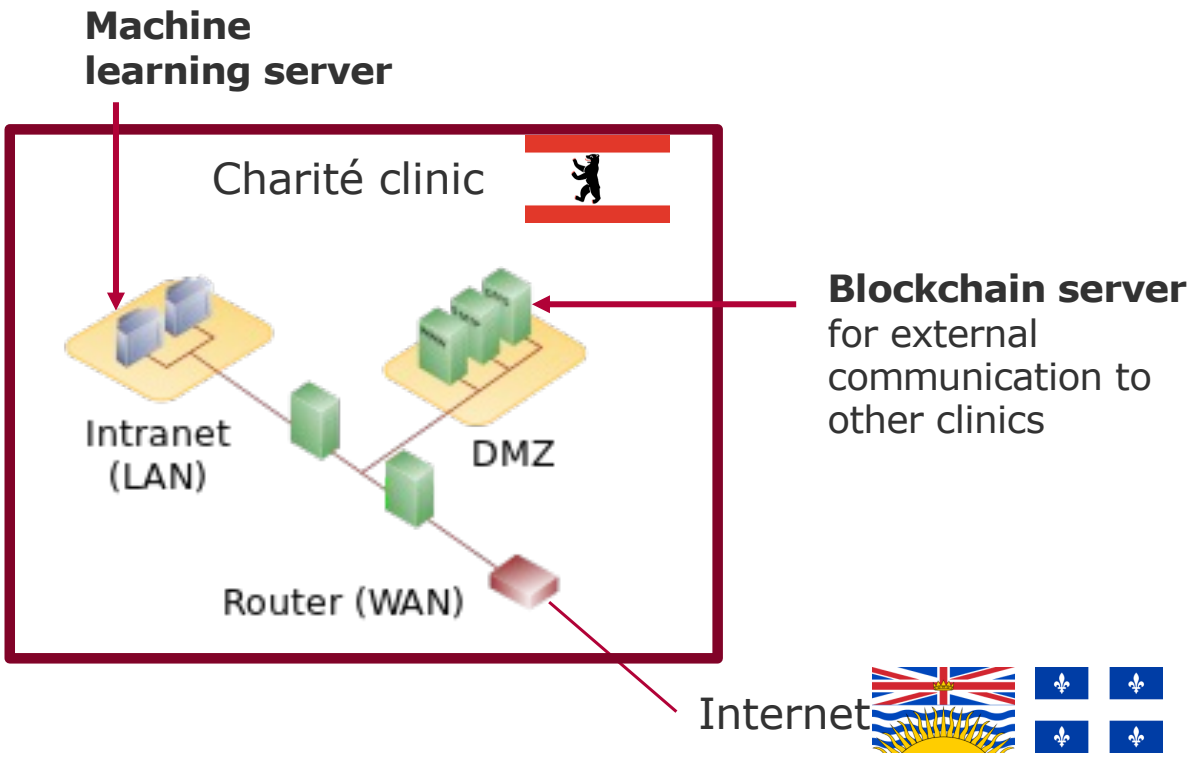
Blockchain

- Originated with the emergence of Bitcoin, today a variety of different blockchain networks exist
- In the scope of our project: **private peer-to-peer network** of **institutions**
- Characteristics:
  - **Replicated** ledger (i.e., each institution stores a copy of the blockchain locally)
  - **Immutable** (i.e., data can be written but cannot be removed)
  - Each institution has **equal rights**
  - **Transparent** and, thus, **auditable**
- Goals in the project:
  - **Communication** between the institutions **through the blockchain**
  - **Store ML models** (or a representation such as hashes) on the blockchain ledger

Proposed two-server setup in case of a demilitarized zone



Blockchain server for external communication to other clinics

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Storing data on the blockchain

- Converting ML models to the hexadecimal format, and converting it back, using Python
- Storing models and retrieving models from the blockchain
  - Successfully store models of up to 32 KB in one transaction
  - For larger transactions
    - Split model into chucks of 32 KB
    - Send one transaction containing header information of the transaction hashes and order of the following transactions which contain the actual ML models
    - Allows sending models of up to 32 MB (1000 transaction hashes can be included in the header)

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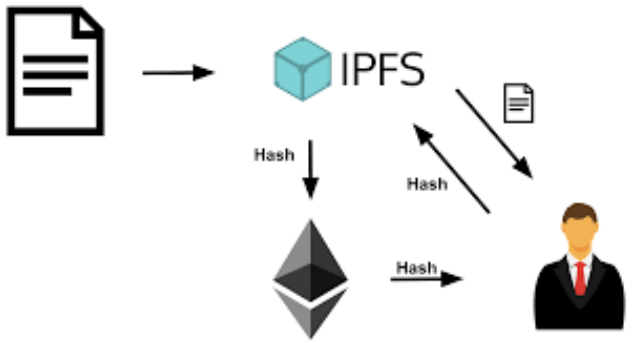
IPFS as a peer to peer file sharing system

- For further scalability, and to keep the blockchain lightweight, we are currently exploring the InterPlanetary File System (IPFS)
  - Private peer to peer network to retrieve files by hashes
  - Other research uses it in combination with blockchains in general, and blockchain-based federated learning
  - Runs on the blockchain server



Images from https://medium.com/pinata/ethereum-and-ipfs-e816e12a3c59

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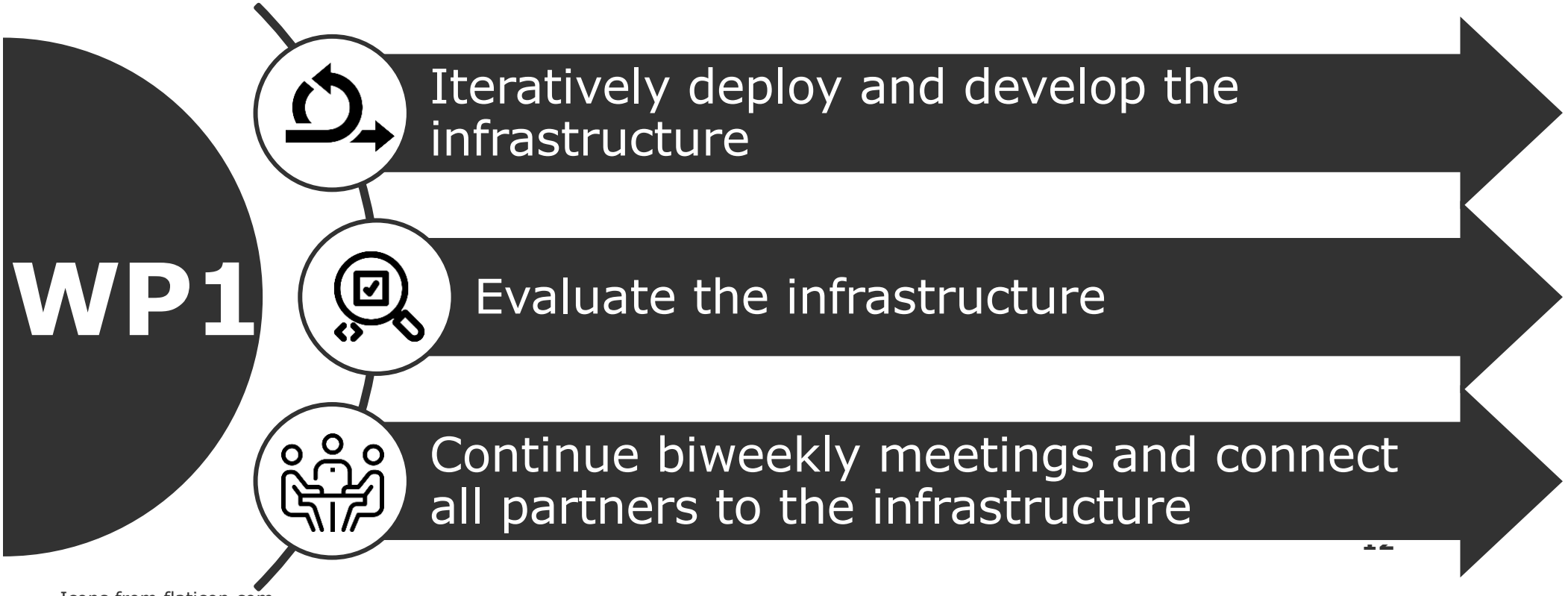
Next steps



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