

# Research Proposal

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## 1. Introduction

Federated Learning involves training a shared global model using local data and compute on various user devices. Several approaches have been proposed to implement this paradigm starting with FedAvg [8]. However, the system heterogeneity in participating devices poses a significant challenge that needs to be addressed. In developing countries, 57% of population are categorised as low-end users. [10] This has implications for fairness due to introduction of systematic bias, in addition to degradation in model accuracy. Recent works such as FedProx [11] and Hassas [9] have attempted to include slow devices by incorporating partial work and serving a subset model according to device characteristics, respectively. These approaches have mostly been evaluated on simulations using LEAF Benchmark [3]. To the best of our knowledge, none of these works have been evaluated on federated learning systems using real-world devices with a sufficiently large number of users.

To this end, we propose the development of a federated learning system that includes 100+ active real-world users. We aim to achieve this by building a robust FL system and deploying a suitable application on top of it. In general, the application will leverage a machine learning model that benefits from collaborative learning in a privacy-preserving manner. It will provide the user with an attractive incentive and will leverage the data, generated through the user's interaction with the application, for model training. Therefore, this will provide a conducive platform to concretely evaluate the robustness of Hassas as well as other FL frameworks. Conducting experiments on real-world data in the face of dynamic changes in systems heterogeneity, including state changes, will provide valuable insights that will benefit the community.

## 2. Related Work

**HeteroFL** challenges the assumption that local models must have the same architecture as the global model. [5] On the other hand, **FedDST** proposes approaches to make on-device computation and in-network communication more efficient. [1] **FedProx** incorporates partial work to include low-end devices [11]. However, these frameworks mostly leverage the **LEAF** benchmark for experimentation. [3] In addition, [4] aims to demonstrate the impact of straggler devices by measuring the impact of cpu resource heterogeneity on training time. The evaluation is conducted using an emulated environment with clients running in Docker containers deployed on a AWS EC2 Virtual Machine instance. The following FL approaches perform evaluations using small-scale testbeds of real-world

devices. **PruneFL** uses a set of Raspberry Pi devices connected to a central server (PC) and a simulated setting. [6] Time measurements from Raspberry Pi devices are used for experiments conducted on the simulated setting. **Hermes** leverages structured pruning to find a small subnetwork for each device and aggregating across overlapping parameters to learn a structured sparse deep neural network. [7] The framework is evaluated on a testbed of 3 Google Pixel smartphones connected to a central server. Similarly, [13] utilized a testbed of 4 devices with different device characteristics to evaluate their approach using the MNIST dataset. Hence, we find few works that have performed evaluations on real-world devices.

## 3. Preliminary Design

### 3.1. Android Application

Our application in target will be a specific University dedicated chatbot which handles a user's questions related to Graduate and Undergraduate level applications and academic assistance. Essentially our user will interact with our chatbot over a mobile application, where question will be provided as input. The question will be given as an input to our Deep Neural Network model on the user's device which will then produce an output as answer. [12] We will require user to provides us with the feedback for the query related answer, to improve the model. Our application will perform some pre-processing and then cache each question and answer pair with the feedback given, to later allow for the model to be trained on the device.

### 3.2. FL Platform

#### Client Runtime

- Model Training
- Device Analytics

No personally identifiable information will be logged.

- Logs
- Device OS
- Device Model
- Device State
- Training time
- Memory profile
- Battery profile

#### Server Runtime

### 3.3. Coordination Layer

This layer will be responsible for tackling practical deployment issues at scale. For example, device execution may be interrupted, resource utilization may be ineffective, or device connectivity could be unreliable.

**Device Management** The selection and reporting of devices for FL tasks are part of device management. In order to make the device management process inclusive, we add functionality to the mechanism described in [2]. Devices that meet the eligibility requirements check in with the server for any FL tasks that are open as part of the selection process. After allocating the FL tasks to available devices, the server waits for participants to report updates. To signal the end of a round, the server uses a goal counter and timer. The goal count is split into two quorums, one for high-end devices and the other for low-end devices, both of equal size. The round is marked complete if the goal count is achieved within the timeout value else the round is discarded.

**Failure Detection** The device is declared failed if it violates the eligibility criteria during a FL round (unmetered connection, plugged in, idle). During the FL round, the failure is detected using the ping and ack mechanism between the server and the device. This aids the server in keeping track of active participants of a FL round.

## 4. Approach

The tasks we need to accomplish can be broadly categorized as follows.

1. Application Development
2. FL Platform Development
3. User Base Development

### 4.1. Phase I

We will begin by developing an android application. Simultaneously, we will develop an end-to-end prototype of the FL platform for 4 devices. Once a working prototype is in place, the next step will be to scale it to 20 users and perform thorough end-to-end testing. The primary objective is to ensure efficient, seamless deployment of the FL platform on a sufficiently large number of clients.

### 4.2. Phase II

Once this is achieved, we will integrate our android application with the FL platform.

### 4.3. Phase III

Finally, we will make an effort to scale our application to 100+ users.

## 5. Timeline and Work Division

Timeline and division of work.

## References

- [1] BIBIKAR, S., VIKALO, H., WANG, Z., AND CHEN, X. Federated dynamic sparse training: Computing less, communicating less, yet learning better. *CoRR abs/2112.09824* (2021).
- [2] BONAWITZ, K. A., EICHNER, H., GRIESKAMP, W., HUBA, D., INGERMAN, A., IVANOV, V., KIDDON, C., KONEČNÝ, J., MAZZOCCHI, S., MCMAHAN, H. B., OVERVELDT, T. V., PETROU, D., RAMAGE, D., AND ROSELANDER, J. Towards federated learning at scale: System design. *CoRR abs/1902.01046* (2019).
- [3] CALDAS, S., WU, P., LI, T., KONEČNÝ, J., MCMAHAN, H. B., SMITH, V., AND TALWALKAR, A. LEAF: A benchmark for federated settings. *CoRR abs/1812.01097* (2018).
- [4] CHAI, Z., FAYYAZ, H., FAYYAZ, Z., ANWAR, A., ZHOU, Y., BARACALDO, N., LUDWIG, H., AND CHENG, Y. Towards taming the resource and data heterogeneity in federated learning. In *2019 USENIX Conference on Operational Machine Learning (OpML 19)* (Santa Clara, CA, May 2019), USENIX Association, pp. 19–21.
- [5] DIAO, E., DING, J., AND TAROKH, V. Heterofi: Computation and communication efficient federated learning for heterogeneous clients. *CoRR abs/2010.01264* (2020).
- [6] JIANG, Y., WANG, S., KO, B. J., LEE, W., AND TASSIULAS, L. Model pruning enables efficient federated learning on edge devices. *CoRR abs/1909.12326* (2019).
- [7] LI, A., SUN, J., LI, P., PU, Y., LI, H., AND CHEN, Y. Hermes: An efficient federated learning framework for heterogeneous mobile clients. In *Proceedings of the 27th Annual International Conference on Mobile Computing and Networking* (New York, NY, USA, 2021), MobiCom '21, Association for Computing Machinery, p. 420–437.
- [8] MCMAHAN, H. B., MOORE, E., RAMAGE, D., AND Y ARCAS, B. A. Federated learning of deep networks using model averaging. *CoRR abs/1602.05629* (2016).
- [9] MUNIR, M. T., SAEED, M. M., ALI, M., QAZI, Z. A., AND QAZI, I. A. Fedprune: Towards inclusive federated learning. *CoRR abs/2110.14205* (2021).
- [10] NASEER, U., BENSON, T. A., AND NETRAVALI, R. Webmedic: Disentangling the memory-functionality tension for the next billion mobile web users. In *Proceedings of the 22nd International Workshop on Mobile Computing Systems and Applications* (New York, NY, USA, 2021), HotMobile '21, Association for Computing Machinery, p. 71–77.
- [11] SAHU, A. K., LI, T., SANJABI, M., ZAHEER, M., TALWALKAR, A., AND SMITH, V. On the convergence of federated optimization in heterogeneous networks. *CoRR abs/1812.06127* (2018).
- [12] VAMSI, G. K., RASOOL, A., AND HAJELA, G. Chatbot: A deep neural network based human to machine conversation model. In *2020 11th International Conference on Computing, Communication and Networking Technologies (ICCCNT)* (2020), pp. 1–7.
- [13] WANG, C., WEI, X., AND ZHOU, P. Optimize scheduling of federated learning on battery-powered mobile devices. In *2020 IEEE International Parallel and Distributed Processing Symposium (IPDPS)* (2020), pp. 212–221.