



FairComp: 2nd International Workshop on Fairness and Robustness in Machine Learning for Ubiquitous Computing

Lakmal Meegahapola*
ETH Zurich
Zurich, Switzerland

Dimitris Spathis†
Nokia Bell Labs
Cambridge, United Kingdom

Marios Constantinides*
Nokia Bell Labs
Cambridge, United Kingdom

Han Zhang
University of Washington
Seattle, USA

Sofia Yfantidou
Aristotle University of Thessaloniki
Thessaloniki, Greece

Niels van Berkel
Aalborg University
Aalborg, Denmark

Anind K. Dey
University of Washington
Seattle, USA

ABSTRACT

How can we ensure that Ubiquitous Computing (UbiComp) research outcomes are ethical, fair, and robust? While fairness in machine learning (ML) has gained traction in recent years, it remains unexplored, or sometimes an afterthought, in the context of pervasive and ubiquitous computing. This workshop aims to discuss fairness in UbiComp research and its social, technical, and legal implications. From a *social perspective*, we will examine the relationship between fairness and UbiComp research and identify pathways to ensure that ubiquitous technologies do not cause harm or infringe on individual rights. From a *technical perspective*, we will initiate a discussion on model generalization and robustness, as well as data processing methods to develop bias mitigation approaches tailored to UbiComp research. From a *legal perspective*, we will examine how new policies shape our community's work and future research. Building on the success of the First FairComp Workshop¹ at UbiComp 2023, we have established a vibrant community centered around the topic of fair, robust, and trustworthy algorithms within UbiComp, while also charting a clear path for future research endeavors in this field.

CCS CONCEPTS

• **Human-centered computing** → Ubiquitous and mobile computing; • **Applied computing** → Consumer health; • **Computing methodologies** → Artificial intelligence; • **Social and professional topics** → Codes of ethics.

*Corresponding author: lakmal.meegahapola@hest.ethz.ch

†Also affiliated with the University of Cambridge, UK.

¹<https://faircomp-workshop.github.io/2023/>

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the author(s) must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

UbiComp Companion '24, October 5–9, 2024, Melbourne, VIC, Australia

© 2024 Copyright held by the owner/author(s). Publication rights licensed to ACM.

ACM ISBN 979-8-4007-1058-2/24/10...\$15.00

<https://doi.org/10.1145/3675094.3677572>

KEYWORDS

fairness; bias; generalization; robustness; privacy; discrimination; responsible AI; ethical AI; UbiComp; Human-Computer Interaction

ACM Reference Format:

Lakmal Meegahapola, Dimitris Spathis, Marios Constantinides, Han Zhang, Sofia Yfantidou, Niels van Berkel, and Anind K. Dey. 2024. FairComp: 2nd International Workshop on Fairness and Robustness in Machine Learning for Ubiquitous Computing. In *Companion of the 2024 ACM International Joint Conference on Pervasive and Ubiquitous Computing Pervasive and Ubiquitous Computing (UbiComp Companion '24), October 5–9, 2024, Melbourne, VIC, Australia*. ACM, New York, NY, USA, 4 pages. <https://doi.org/10.1145/3675094.3677572>

1 INTRODUCTION

Due to the integration of Machine Learning (ML) into Ubiquitous Computing (UbiComp), tasks that were once deemed impossible or reserved exclusively for humans are now within technology's reach. Algorithms running on ubiquitous devices, such as smartphones and wearables, have been employed to recognize human activities [5], track sleep patterns [7], and detect breathing phases [17]. Currently, we witness a surge in high-stakes applications such as diagnosing COVID-19 infections [2], detection of Atrial Fibrillation (AFib) [9], and enhancement of cognitive performance [4]. However, as with any technological advancement, ethical opportunities and risks come hand in hand, and, similar to humans, ML algorithms are susceptible to biases [12].

While fairness research has gained popularity in recent years [13, 19], with a dedicated conference and scientific community (e.g., FAccT, AIES), fairness in UbiComp remains under-explored [21, 24]. However, UbiComp applications are equally likely to suffer from biases [22]. These biases could lead to models that do not generalize well or discriminate against certain populations [6, 10]. For example, health sensors such as oximeters consistently misclassify people of color [18], while client selection in federated learning incorporates biases against user devices with poorer networking capabilities [25]. Similarly, sensing-based models trained on data predominantly from Western European countries have shown declining performance when tested in countries across Asia and the Americas [1, 11].

Ubiquitous data and models have certain particularities, often-times not shared with the broader scholarly discourse on ML ethics. For example, they typically include small-scale, proof-of-concept datasets collected in the lab, making it difficult to extract population-level insights. Moreover, they are mostly sequential/temporal in nature, with biases being harder to surface [23]. In other words, while it is relatively straightforward to distinguish a person’s skin tone from a picture, it is much harder to do so from sensor measurements—as UbiComp strives to blend technologies in the background, biases are blended too [3]. Compounding the problem, the lack of geographical diversity, a dearth of longitudinal studies, and the under-reporting of essential study information create “blind spots” in the research on algorithmic fairness [15, 20]. Finally, as mentioned earlier, given that such technologies are typically developed in Western countries, they tend to reflect the intuition, knowledge, and values of “WEIRD” (Western, Educated, Industrialized, Rich, and Democratic) cultures, potentially limiting their inclusivity and relevance to other contexts [8, 11, 14, 16, 21]. Hence, as the field of ML continues to evolve, the UbiComp community needs to stay vigilant, ensuring that technological advancements are designed and deployed in an ethical and fair manner.

To this end, we aim to spark a discussion about the ethical, social, technical, and legal issues relevant to ethical, fair, and robust research in UbiComp. From a social perspective, we look into how fairness research can be translated into this domain and identify pathways for ensuring that ubiquitous technologies do not cause any harm or infringe on any individual rights [3]. From a technical perspective, we intend to take a closer look at the community’s data collection, processing, and modeling practices to ideate fairness enhancement, improve generalization, and bias mitigation targeted at UbiComp work. From a regulatory perspective, we set out to understand how proposed policies, such as the European AI Act, will frame the work of the community and drive future research. This balance between performance and fairness is envisaged as a viable way forward—an ideal compromise.

These perspectives raise numerous challenges and questions that we seek to address in this workshop. How can we leverage existing fairness research and adapt it to the UbiComp domain? How can we define and quantify fairness in prevalent data (e.g., time series) and model (e.g., regression, multi-class classification) modalities? How can data and labels be acquired ethically? How can we generate fair synthetic data or recruit representative real-world samples? How do we incorporate fairness into our technology development processes and deployment monitoring by design? and How can we develop robust machine learning models that generalize well across populations, leading to equitable outcomes? Essentially, how do we better equip our community to deal with unfairness?

Besides these questions, which hold significance for the UbiComp community, several challenges extend to other disciplines, including Philosophy, Sociology, Law, Psychology, or any of the broad range of subjects contributing to this area. Which ethical challenges arise when technologies are interwoven into everyday life until they are indistinguishable from it? What are the historical and systemic biases that frame the domain’s research? How can ubiquitous applications be regulated without stifling innovation?

2 FAIRCOMP WORKSHOP

We aim FairComp to be an interdisciplinary forum beyond just presenting papers, where we can bring together academia and industry. Notably, we reach out to researchers and practitioners whose work lies within the ACM SIGCHI domains (e.g., UbiComp, HCI, CSCW), as well as FAccT, ML & AI, Social sciences, Philosophy, Law, Psychology, and others. The workshop organizers are actively engaged in the aforementioned themes and will encourage their network of colleagues and students to participate. In particular, the goal of this workshop is to collaboratively:

- *Assess* the evolving socio-technical themes and concerns in relation to fairness across ubiquitous technologies, ranging from health, behavioural, and emotion sensing to human-activity recognition, mobility, and navigation.
- *Map* the space of ethical risks and possibilities regarding technological interventions (e.g., input modalities, learning paradigms, design choices).
- *Envision* new sensing and data-acquisition paradigms to fairly and accurately gather ubiquitous physical, physiological, and experiential qualities.
- *Explore* novel methods for generalization, domain adaptation, and bias mitigation and investigate their suitability for diverse ubiquitous case studies.
- More generally, *initiate* a discourse around the future of “ubiquitous fairness” and co-create research agenda(s) to meaningfully address it.
- Finally, *consolidate* an international network of researchers to further develop these research agendas through funding proposals and through steering future funding instruments.

Relevance and Impact to UbiComp. With its strong community engaged in several themes (e.g., sensing, HCI, AI/ML), and its cross-disciplinary focus across various areas (Sociology, Philosophy, Health Informatics, Law), UbiComp plays a key role in paving the way for responsible, robust, and fair technological advancements. Coupled with the unique characteristics of ubiquitous technology, these advancements demand the development of distinct definitions, metrics, and methodologies to counteract the effects of bias. Building on the success of last year’s FairComp, we have established a subcommunity focused on fairness and robustness within UbiComp. By raising awareness, we aim to encourage the integration of fairness in our research process and artifacts. Collaborating with other disciplines, this workshop aims to promote scientific exchange and jointly create a comprehensive and effective framework for ensuring fairness in UbiComp technology.

Long-term Objectives. This workshop will contribute to a deeper understanding of ethical challenges and opportunities surrounding the robust and fair use of ubiquitous technology. Under such efforts, we plan to build an active and long-lasting community around the workshop’s theme. Finally, we intend to leverage the workshop’s momentum and the associated research agendas to prepare a special issue in a relevant journal (e.g., IEEE Pervasive Comp.) after the conclusion of the workshop. After the workshop, we plan to distribute an open call, with a focus on engaging the workshop participants to submit extended versions of their work. Finally, we will consolidate our workshop’s insights into an article.

Table 1: Proposed schedule for the FairComp workshop.

	Time	Activity
Session I	09:00–09:15	Welcome: Introduce organizers, participants, workshop objectives, and schedule.
	09:15–10:15	Keynote #1: Presentation by an invited expert (45-min talk followed by 15-min Q&A).
	10:15–10:45	Paper presentations #1: 2 paper presentations (10-min talk followed by 5-min Q&A).
	10:45–11:00	Short Break
	11:00–12:00	Interactive Activity: Collaborative ideation session in small groups about the ethical, social, technical, and legal perspectives of UbiComp fairness.
	12:00–13:30	Lunch Break
Session II	13:30–14:30	Keynote #2: Presentation by an invited expert (45-min talk followed by 15-min Q&A).
	14:30–15:15	Paper presentations #2: 3 paper presentation (10-min talk followed by 5-min Q&A).
	15:15–15:45	Short Break
	15:45–16:30	Panel Discussion: Keynote speakers and invited industry experts discuss the topic of “Ethical & Responsible UbiComp: a case for fairness and robustness”.
	16:30–17:00	Wrap Up: Closing remarks.

3 WORKSHOP STRUCTURE

Workshop Topics. The workshop aims to provide a platform for exchanging ideas that can shape the future of ubiquitous computing fairness and beyond, and to rethink the role of UbiComp as an enabler of pervasive experiences free from biases. The main topics of interest include, but are not limited to: new definitions, metrics, and criteria of fairness and robustness, tailored for ubiquitous computing; bias identification and mitigation; geographical equity; and model robustness.

Workshop Format. We plan for an open, full-day workshop with two invited keynotes and five paper presentations (two accepted workshop papers and three invited IMWUT papers), covering completed and ongoing original empirical works, reviews, as well as position papers. All papers will be presented as talks, including Q&A to allow researchers to engage in discussion with the workshop attendees. Beyond papers, to make for a more lively experience, FairComp will include two interactive activities: a collaborative ideation session, where participants will be split into small groups to discuss the ethical, social, technical, and legal perspectives of UbiComp fairness under the guidance of invited experts, guided by topics set by the organizers; and an interactive panel on “*Ethical & Responsible UbiComp: A Case for Fairness and Robustness*” with keynote speakers and industry experts to further discuss reflections on their work with an open Q&A session with the audience, moderated by one of the co-organizers. For keynotes and panel discussions, we plan to invite leading experts who have worked on topics related to the themes of the workshop. Hence, the workshop is estimated to last around 8 hours as illustrated in Table 1.

Estimated Number of Participants. We consider 20-25 attendees an appropriate size for our workshop, allowing us to shape a comprehensive future research agenda, build collaborations, and consolidate an active community on the topic.

Paper Selection and Publication. Submissions will be reviewed by at least two or three reviewers (including organizers and external reviewers) and will be published by ACM. Our acceptance criteria will be defined by the combination of relevance, novelty, provocativeness, and research quality. Given the timely theme of this workshop, we aim to attract a sufficient number of paper submissions that will enable us to organize a high-quality workshop.

Pre-workshop Activities. We will disseminate the call for papers (CfP) through diverse channels, including mailing lists, our social and professional networks, local ACM chapters, the dedicated workshop website, and our respective institutional communication channels. The website (<https://faircomp-workshop.github.io/2024/>) will be a key platform to disseminate information, including the CfP, crucial deadlines, profiles of the co-organizers, Technical Program Committee (TPC), workshop schedule, and activities. Moreover, the website will also serve as an archive of the workshop outcomes, containing the workshop’s summary and other outputs. Upon acceptance, we will reach out to experts from academia and industry to compose a TPC to review and select author contributions and facilitate preparing a diverse and thematically rich program.

Post-workshop Activities. During and following the workshop, the results and outcomes will be blogged on the workshop website and disseminated in ACM Interactions. Drawing on the workshop submissions and interactive activities, we will propose a journal special issue (e.g., IEEE Pervasive) and encourage participants to collaborate on submissions around the developed research agendas.

Diversity Statement and Accessibility. Our workshop is committed to creating a welcoming and inclusive environment for all attendees, regardless of race, gender, sexual orientation, religion, or ability. This belief will be implemented by ensuring the diverse selection of organizers, TPC members, and speakers, disseminating the CfP in mailing lists targeting under-represented communities in computing, promoting inclusive language, and disseminating the conference’s code of conduct. Prior to submission, the authors will be asked to adhere to UbiComp’s Accessible Submission Guidelines.² Finally, in the weeks leading up to the workshop, we will conduct a survey with attendees to identify the accessibility needs for in-person participation to accommodate during the workshop in collaboration with the JEDI Chairs.

4 ORGANIZERS

Lakmal Meegahapola is a postdoctoral researcher at ETH Zurich. He obtained his PhD from EPFL in 2024 and has also worked at Google Research, Nokia Bell Labs, the University of Cambridge, and Singapore Management University. His work lies at the intersection of mobile and wearable sensing, digital health, and machine learning, where he develops robust AI/ML models for multimodal time series data. He is on the editorial board of IEEE Pervasive Computing and also is an Associate Chair of ACM CHI. **Website:** <https://lakmalmeegahapola.com/>

Dimitris Spathis is a senior research scientist at Nokia Bell Labs (UK) and a visiting researcher at the University of Cambridge. His work enables AI to make the most out of real-world multimodal

²<https://www.ubicomp.org/ubicomp-iswc-2024/accessibility/accessibility-guidelines/>

and sequential data through label-efficient and robust ML. He previously worked at Microsoft Research, Telefonica Research, and Ocado. His experience as an organizer of scientific meetings includes WellComp and FairComp at Ubicomp '22-23, HCRL at AAAI '24, CHIL '23, and ML4H co-located with NeurIPS '22. He is on the editorial boards of Nature Digital Medicine and IEEE Pervasive Comp. **Website:** <https://dispathis.com/>

Marios Constantinides is a Senior Research Scientist at Nokia Bell Labs (UK) and a visiting researcher at the University of Cambridge. He works in the areas of HCI, UbiComp, and responsible AI. His current research focuses on building AI-based technologies that augment people's interactions and communication, with a particular focus on the workplace. He has previously organized workshops at UbiComp and Special Interests Groups at CHI on future of work and responsible AI. **Website:** <https://comarios.com/>

Sofia Yfantidou is a Data Scientist at Kinetic Analysis, aiming at improving life quality with human motion data. She holds a PhD in "Human-centered Machine Learning for Mobile and Wearable Sensing Data" from the Aristotle University of Thessaloniki, for which she received a Marie Skłodowska-Curie fellowship. **Website:** <https://www.linkedin.com/in/sofiayfantidou/>

Han Zhang is a 4th-year PhD student at the University of Washington. Her works lie in the intersection of human-computer interaction, ubiquitous computing, applied machine learning, and data science. Her current research primarily focuses on modeling human behaviors through mobile and wearable sensing technologies, as well as designing responsible interactive tools tailored for various stakeholders to support human well-being. She has organized workshops at Ubicomp and participated in FairComp '23. **Website:** <https://make4all.org/portfolio/han-zhang/>

Niels van Berkel is an Associate Professor at Aalborg University. He focuses on the design and evaluation of intelligent computing systems to support human cognition. He has previously organised workshops at UbiComp and CHI, and serves on the editorial board of IJHCS. **Website:** <https://www.nielsvanberkel.com/>

Anind K. Dey is the Dean and Professor of the Information School at the University of Washington. For more than 20 years, his research has focused at the intersection of human-computer interaction, machine learning and ubiquitous computing. He has organized many workshops, and served as the Papers Chair for CHI, and the papers chair and general chair for Ubicomp. **Website:** <https://ischool.uw.edu/people/faculty/profile/anind>

REFERENCES

- [1] Karim Assi, Lakmal Meegahapola, William Droz, Peter Kun, Amalia De Götzen, Miriam Bidoglia, Sally Stares, George Gaskell, Altangerel Chagnaa, Amarsanaa Ganbold, et al. 2023. Complex daily activities, country-level diversity, and smartphone sensing: A study in denmark, italy, mongolia, paraguay, and uk. In *Proceedings of the 2023 CHI conference on human factors in computing systems*.
- [2] Chloë Brown, Jagmohan Chauhan, Andreas Grammenos, Jing Han, Apinan Hasthanasombat, Dimitris Spathis, Tong Xia, Pietro Cicuta, and Cecilia Mascolo. 2020. Exploring Automatic Diagnosis of COVID-19 from Crowdsourced Respiratory Sound Data. In *KDD 2020 (KDD '20)*.
- [3] Marios Constantinides and Daniele Quercia. 2022. Good Intentions, Bad Inventions: How Employees Judge Pervasive Technologies in the Workplace. *IEEE Pervasive Computing* (2022).
- [4] Jean Costa, François Guimbretière, Malte F Jung, and Tanzeem Choudhury. 2019. Boostmeup: Improving cognitive performance in the moment by unobtrusively regulating emotions with a smartwatch. *IMWUT* (2019).
- [5] Fuqiang Gu, Mu-Huan Chung, Mark Chignell, Shahrokh Valaee, Baoding Zhou, and Xue Liu. 2021. A survey on deep learning for human activity recognition. *CSUR* (2021).
- [6] Nathan Kammoun, Lakmal Meegahapola, and Daniel Gatica-Perez. 2023. Understanding the Social Context of Eating with Multimodal Smartphone Sensing: The Role of Country Diversity. In *Proceedings of the 25th International Conference on Multimodal Interaction (ICMI '23)*.
- [7] Heli Koskimäki, Hannu Kinnunen, Teemu Kurppa, and Juha Röning. 2018. How do we sleep: a case study of sleep duration and quality using data from our ring.
- [8] Sebastian Linxen, Christian Sturm, Florian Brühlmann, Vincent Cassau, Klaus Opwis, and Katharina Reinecke. 2021. How weird is CHI?
- [9] Steven A Lubitz, Anthony Z Faranesh, Caitlin Selvaggi, Steven J Atlas, David D McManus, Daniel E Singer, Sherry Pagoto, Michael V McConnell, Alexandros Pantelopoulou, and Andrea S Foulkes. 2022. Detection of atrial fibrillation in a large population using wearable devices: the Fitbit heart study. *Circulation* (2022).
- [10] Aurel Ruben Mäder, Lakmal Meegahapola, and Daniel Gatica-Perez. 2024. Learning About Social Context From Smartphone Data: Generalization Across Countries and Daily Life Moments. In *Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI '24)*.
- [11] Lakmal Meegahapola, William Droz, Peter Kun, Amalia De Götzen, Chaitanya Nutakki, Shyam Diwakar, Salvador Ruiz Correa, Donglei Song, Hao Xu, Miriam Bidoglia, et al. 2023. Generalization and personalization of mobile sensing-based mood inference models: an analysis of college students in eight countries. *Proceedings of the ACM on interactive, mobile, wearable and ubiquitous technologies* (2023).
- [12] Ninareh Mehrabi, Fred Morstatter, Nripsuta Saxena, Kristina Lerman, and Aram Galstyan. 2021. A survey on bias and fairness in machine learning. *ACM computing surveys (CSUR)* (2021).
- [13] Ninareh Mehrabi, Fred Morstatter, Nripsuta Saxena, Kristina Lerman, and Aram Galstyan. 2021. A Survey on Bias and Fairness in Machine Learning. *CSUR* (2021).
- [14] Alexandre Nanchen, Lakmal Meegahapola, William Droz, and Daniel Gatica-Perez. 2023. Keep Sensors in Check: Disentangling Country-Level Generalization Issues in Mobile Sensor-Based Models with Diversity Scores. In *Proceedings of the 2023 AAAI/ACM Conference on AI, Ethics, and Society (AI/ES '23)*.
- [15] Laura Schelenz, Ivano Bison, Matteo Busso, Amalia de Götzen, Daniel Gatica-Perez, Fausto Giunchiglia, Lakmal Meegahapola, and Salvador Ruiz-Correa. 2021. The Theory, Practice, and Ethical Challenges of Designing a Diversity-Aware Platform for Social Relations. In *Proceedings of the 2021 AAAI/ACM Conference on AI, Ethics, and Society (Virtual Event, USA) (AI/ES '21)*.
- [16] Ali Akbar Septiandri, Marios Constantinides, Mohammad Tahaei, and Daniele Quercia. 2023. WEIRD FAccTs: How Western, Educated, Industrialized, Rich, and Democratic is FAccT?. In *2023 ACM Conference on Fairness, Accountability, and Transparency (FAccT '23)*. ACM.
- [17] Chen-Hsuan (Iris) Shih, Naofumi Tomita, Yanick X. Lukic, Álvaro Hernández Reguera, Elgar Fleisch, and Tobias Kowatsch. 2020. Breeze: Smartphone-Based Acoustic Real-Time Detection of Breathing Phases for a Gamified Biofeedback Breathing Training. *IMWUT* (2020).
- [18] Michael W Sjoding, Robert P Dickson, Theodore J Iwashyna, Steven E Gay, and Thomas S Valley. 2020. Racial bias in pulse oximetry measurement. *NEJM* (2020).
- [19] Mohammad Tahaei, Marios Constantinides, Daniele Quercia, Sean Kennedy, Michael Muller, Simone Stumpf, Q Vera Liao, Ricardo Baeza-Yates, Lora Aroyo, Jess Holbrook, et al. 2023. Human-Centered Responsible Artificial Intelligence: Current & Future Trends. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*.
- [20] Niels van Berkel, Zhanna Sarsenbayeva, and Jorge Goncalves. 2023. The methodology of studying fairness perceptions in Artificial Intelligence: Contrasting CHI and FAccT. *International Journal of Human-Computer Studies* (2023).
- [21] Sofia Yfantidou, Marios Constantinides, Dimitris Spathis, Athena Vakali, Daniele Quercia, and Fahim Kawsar. 2023. Beyond Accuracy: A Critical Review of Fairness in Machine Learning for Mobile and Wearable Computing.
- [22] Sofia Yfantidou, Pavlos Sermpetzis, Athena Vakali, and Ricardo Baeza-Yates. 2023. Uncovering Bias in Personal Informatics. *Proc. ACM Interact. Mob. Wearable Ubiquitous Technol.* (sep 2023).
- [23] Sofia Yfantidou, Dimitris Spathis, Marios Constantinides, Athena Vakali, Daniele Quercia, and Fahim Kawsar. 2024. Evaluating Fairness in Self-supervised and Supervised Models for Sequential Data. In *A collection of the accepted papers for the Human-Centric Representation Learning workshop at AAAI 2024 (HCLR at AAAI 2024)*.
- [24] Han Zhang, Leijie Wang, Yilun Sheng, Xuhai Xu, Jennifer Mankoff, and Anind K Dey. 2023. A Framework for Designing Fair Ubiquitous Computing Systems. In *Adjunct Proceedings of the 2023 ACM International Joint Conference on Pervasive and Ubiquitous Computing & the 2023 ACM International Symposium on Wearable Computing*.
- [25] Pengyuan Zhou, Hengwei Xu, Lik Hang Lee, Pei Fang, and Pan Hui. 2022. Are you left out? an efficient and fair federated learning for personalized profiles on wearable devices of inferior networking conditions. *IMWUT* (2022).