Breaking edge shackles: Infrastructure-free collaborative mobile augmented reality

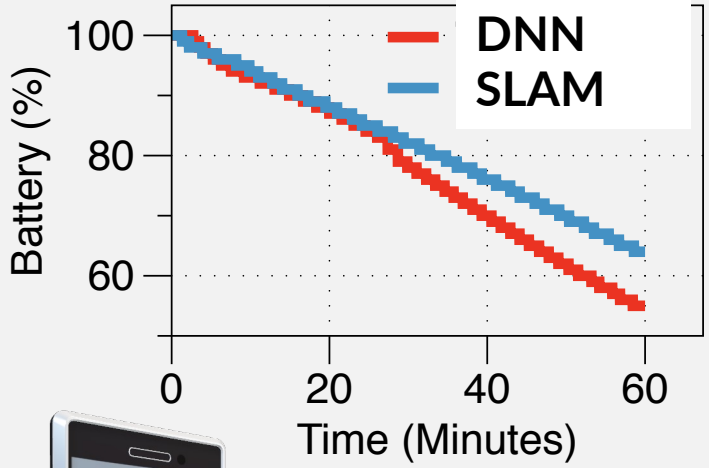
Kittipat Apicharttrisorn, Jiasi Chen, Vyas Sekar,
Anthony Rowe, Srikanth V. Krishnamurthy

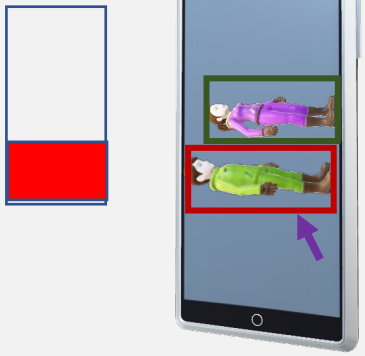
UC RIVERSIDE Carnegie Mellon University

2022 ACM SenSys, November 7th, 2022

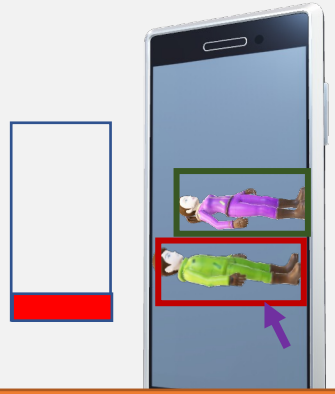
Motivation

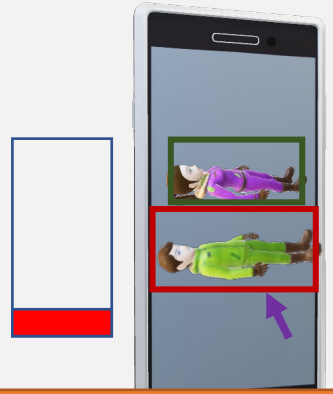
Emergency response

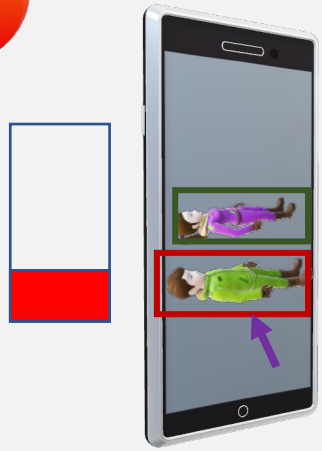




AR device







AR device

- Scenario: No wireless or edge infrastructure to offload computations
- Observations: Redundancy across AR devices which detect same set of objects with DNNs, explore same physical spaces using SLAM

Design goals

- Distribute compute-heavy AR tasks across devices which collaborate through message exchanges
- Work natively on AR devices without infrastructure (e.g. no edge offloading or wireless infrastructure)
- Efficient in coping with gradual and abrupt motions

Problem statement

Can we enable a rich AR experience in infrastructure-free settings, running natively on user devices, without significant energy drain?

Key idea

- *Collaborative time slicing* distributes compute heavy tasks among devices

Challenges

- Synchronizing moving AR devices in new areas
- Representing virtual overlays in 3D coordinates
- Recovering from failures due to abrupt motion

Contributions

- Identify fundamental challenges in existing systems to support infrastructure-free AR
- Design the first infrastructure-free AR system, **FreeAR**, incorporating novel and power efficient components.
- Implement an end-to-end prototype on Android and evaluate it through extensive experiments
  - improves virtual overlay placement accuracy by up to 78%
  - reduces power by up to 60%

AR design space

Focus on power efficiency

Multi-user

Google's ARCore
SPAR (CoNEXT 20)
Edge-Sharing (Infocom 21)

FreeAR
AVR (MobiSys 18)

Single-user

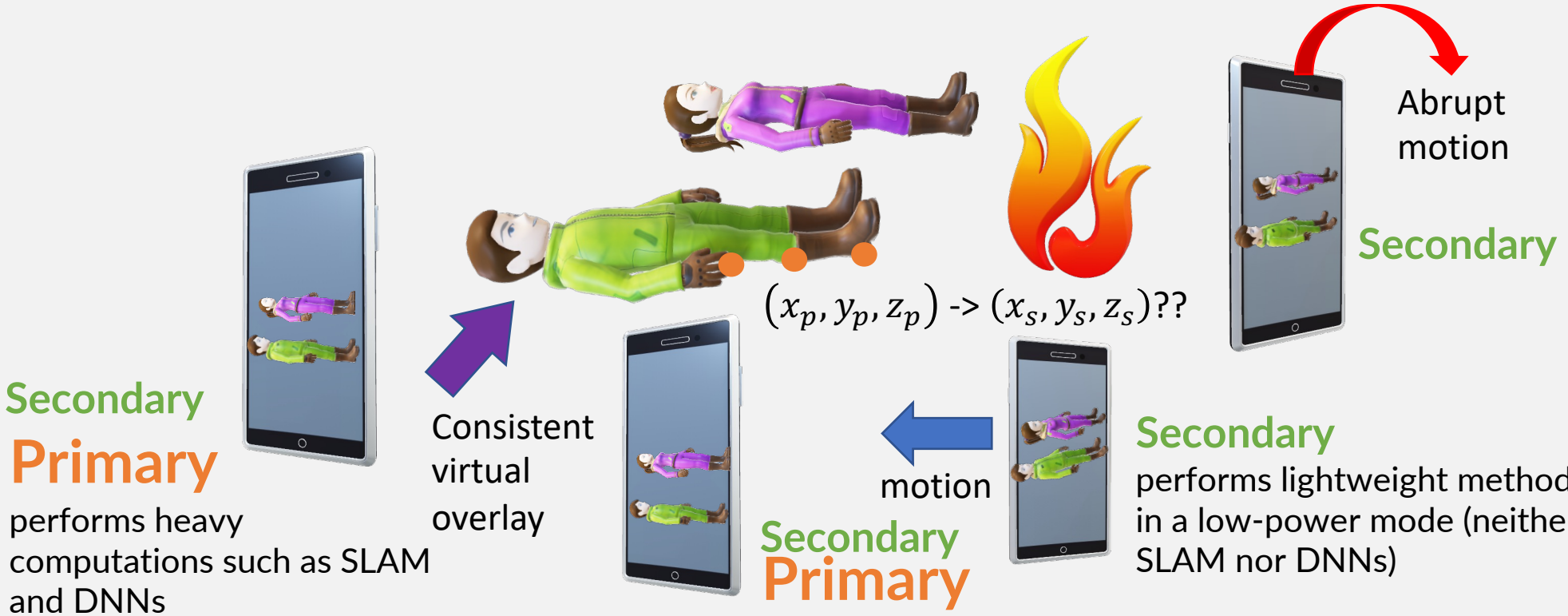
Edge-SLAM (MobiSys 20)
MARVEL (SenSys 18)
Liu et al. (MobiCom 19)

MARLIN (SenSys 19)
Google's Objectron

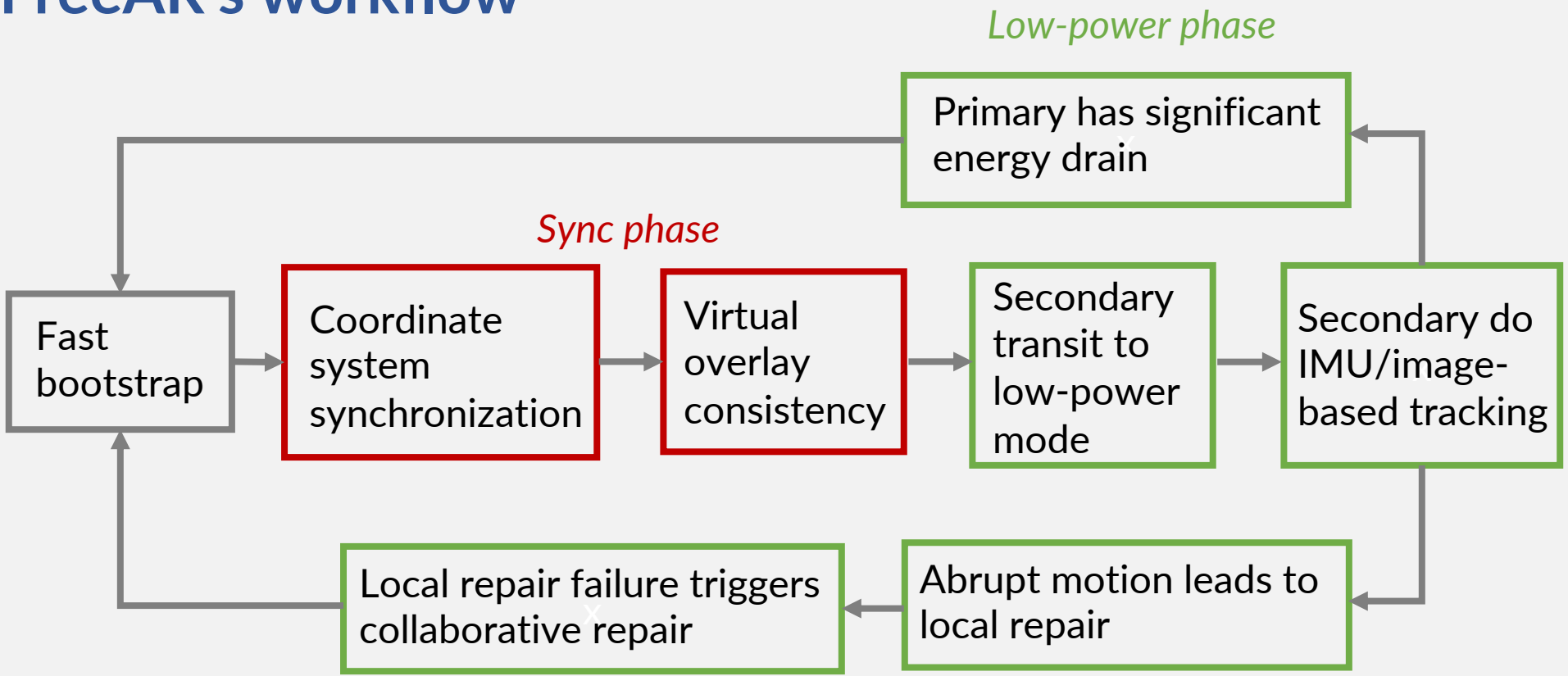
Need infrastructure

Infrastructure-free

FreeAR's *collaborative time slicing* distributes energy expenditure and improves AR longevity.

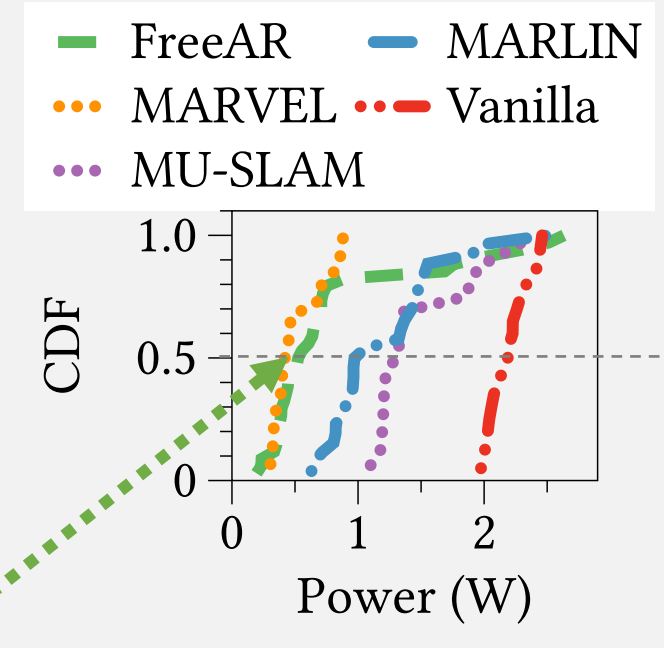


FreeAR's workflow

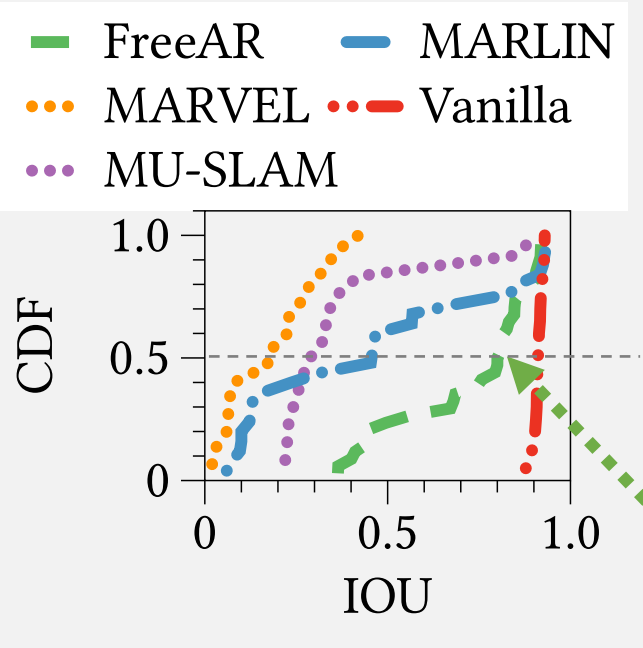


End-to-end evaluations: 15 AR sessions with 2-5 users

MARVEL: edge-assisted AR
MARLIN: on-device DNN energy optimization
Multi-user SLAM: all devices run SLAM
Vanilla: running DNNs and SLAM without energy concern.



FreeAR consumes only 0.5 W of power because of low-power modes on secondary devices



FreeAR improves IOU over baselines because of DNNs on local views and efficient repair methods

Breaking edge shackles: Infrastructure-free collaborative mobile AR

- FreeAR's collaborative time slicing reuse/reduce heavy-compute tasks in AR.
- It tackles key synchronization, consistency and recovery challenges in decentralized AR operations.
- It significantly reduces power consumption and improves virtual overlay placement accuracy for the AR users.
- It allows, perhaps for the first time, the users to engage in AR experience on the fly without needing infrastructure support!

Questions?

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