Towards Supporting Millions of Users in Modifiable Virtual Environments by Redesigning Minecraft-Like Games as Serverless Systems

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Gaming by the Numbers

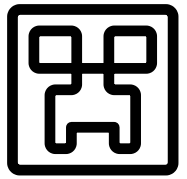
The 2019 annual revenue from the gaming industry was **$152.1 billion**

- More than 10 times US recorded music revenue
- More than 3 times the global box office revenue

Minecraft has sold more than **200 million copies**

More than **126 million people** play Minecraft every month

- More than the number of users of MacOS

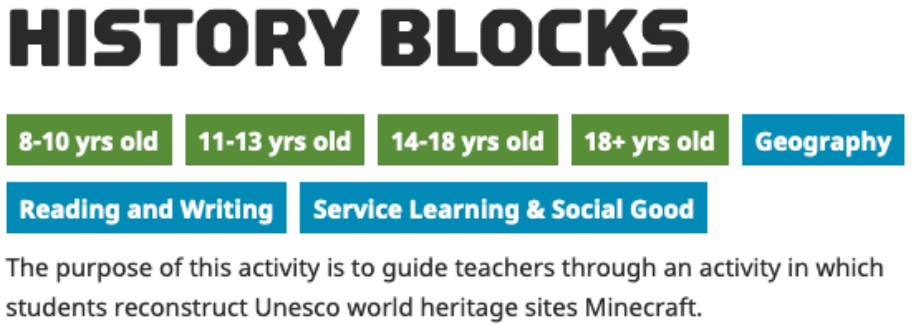


Sources: https://news.xbox.com/en-us/2020/05/18/minecraft-connecting-more-players-than-ever-before/, https://www.comscore.com/Insights/Press-Releases/2020/1/Comscore-Reports-Highest-Ever-Worldwide-Box-Office, https://www.riaa.com/riaa-releases-2019-year-end-music-industry-revenue-report/, https://techcrunch.com/2017/04/04/apple-pushes-the-reset-button-on-the-mac-pro/

Features of Modifiable Virtual Environments (MVEs) are Generally Beneficial

Uses of MVEs include:

1. Entertainment
2. Education
3. Activism
4. Bringing people together in times of crisis



How Greenpeace Used Minecraft to Stop Illegal Logging in Europe's Last Lowland Primeval Forest

Good game, everybody

By Angela Natividad | January 22, 2018

Pussy Riot, Idles to play Minecraft virtual festival 'Block by Blockwest'

It starts this Saturday

By Makena Kelly | @kellymakena | Apr 22, 2020, 1:33pm EDT

Minecraft: Connecting More Players Than Ever Before

by Helen Chiang, Studio Head, Mojang Studios • May 18, 2020 @ 6:00am

Sources: http://www.adweek.com/creativity/how-greenpeace-used-minecraft-to-stop-illegal-logging-in-europes-last-lowland-primeval-forest/, https://news.xbox.com/en-us/2020/05/18/minecraft-connecting-more-players-than-ever-before/, https://education.minecraft.net/lessons/history-blocks, https://www.theverge.com/2020/4/22/21231359/pussy-riot-idles-minecraft-festival-block-by-blockwest

MVE Scalability Challenge

Minecraft supports 126 million active monthly players, but only by using **isolated instances** that do not scale beyond **a few hundred players**.[1]

Pussy Riot, Idles to play Minecraft virtual festival 'Block by Blockwest'

It starts this Saturday

By Makena Kelly | @kellymakena | Apr 22, 2020, 1:33pm EDT

Minecraft music festival Block By Blockwest postponed after servers crash

Over 100,000 people logged on to catch virtual performances by Massive Attack and more

By **Patrick Clarke** | 26th April 2020

Sources: 1: Yardstick: A benchmark for minecraft-like services, Jerom van der Sar et al. ICPE2019.
https://www.nme.com/news/music/minecraft-music-festival-block-by-blockwest-postponed-after-servers-crash-2653948

Definition of a Modifiable Virtual Enviroment (MVE)

A modifiable virtual environment is a real-time, online, multi-user environment which allows its users (i.e., players) to:

1. modify the virtual world's ***objects*** (e.g., player apparel)
2. modify the virtual world's ***parts*** (e.g., terrain)
3. create new content by ***connecting components***
4. interact with the world through ***programs***




Unique to MVEs

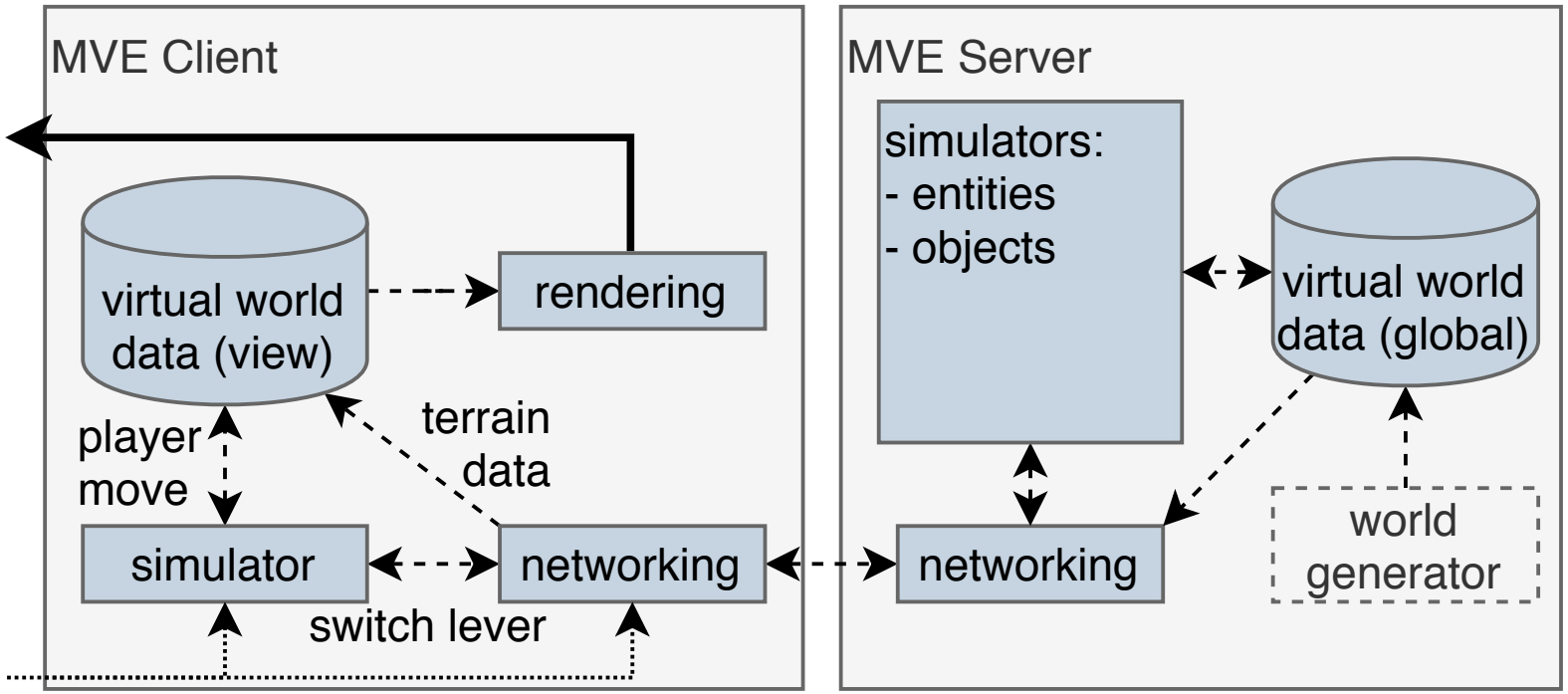
Main Contributions

1. We model current MVEs, and describe how these game instances are currently deployed as cloud services
2. We envision for large-scale MVEs. In our vision, MVEs are serverless; running as a collection of services
3. To move towards our vision, we propose three challenging and timely areas of research

MVE Model and Deployment

Inside a Modifiable Virtual Environment

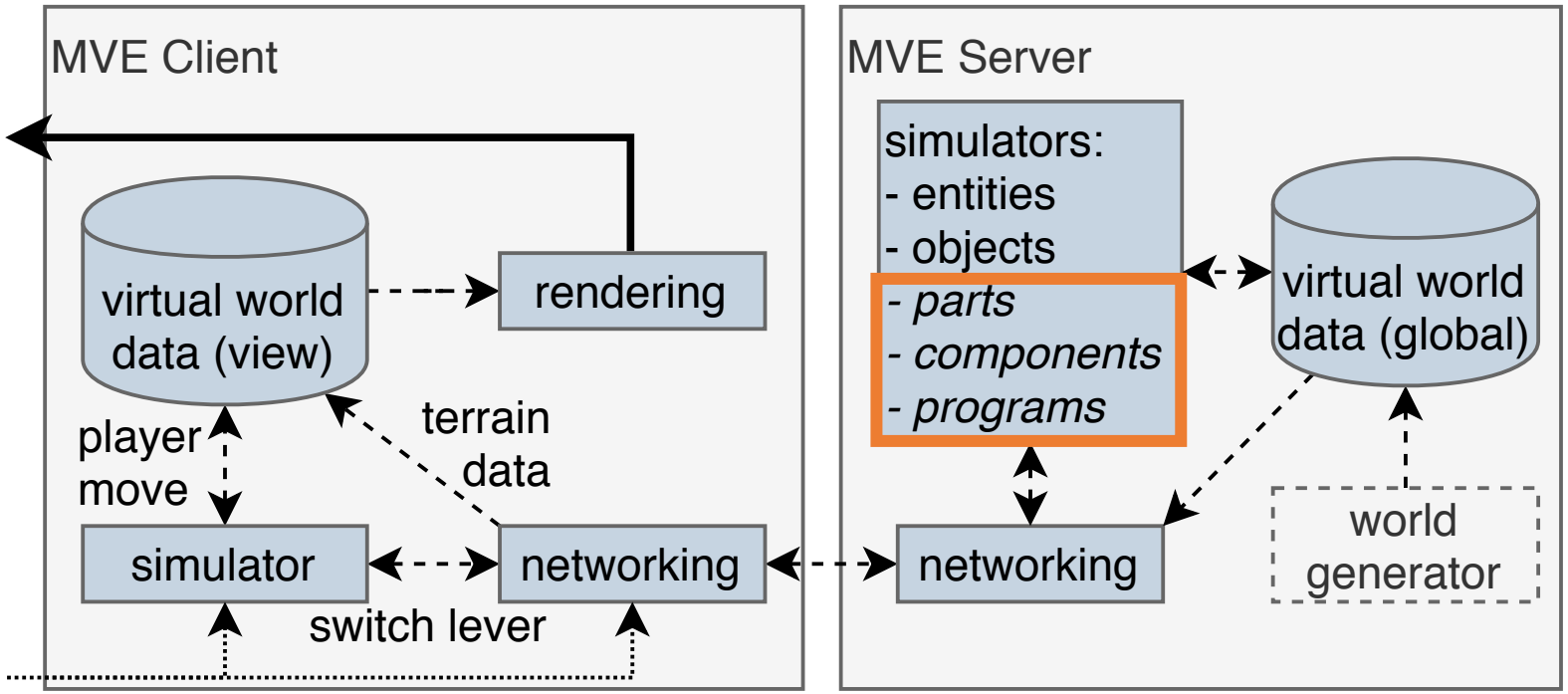
MVEs typically use a clients/server architecture



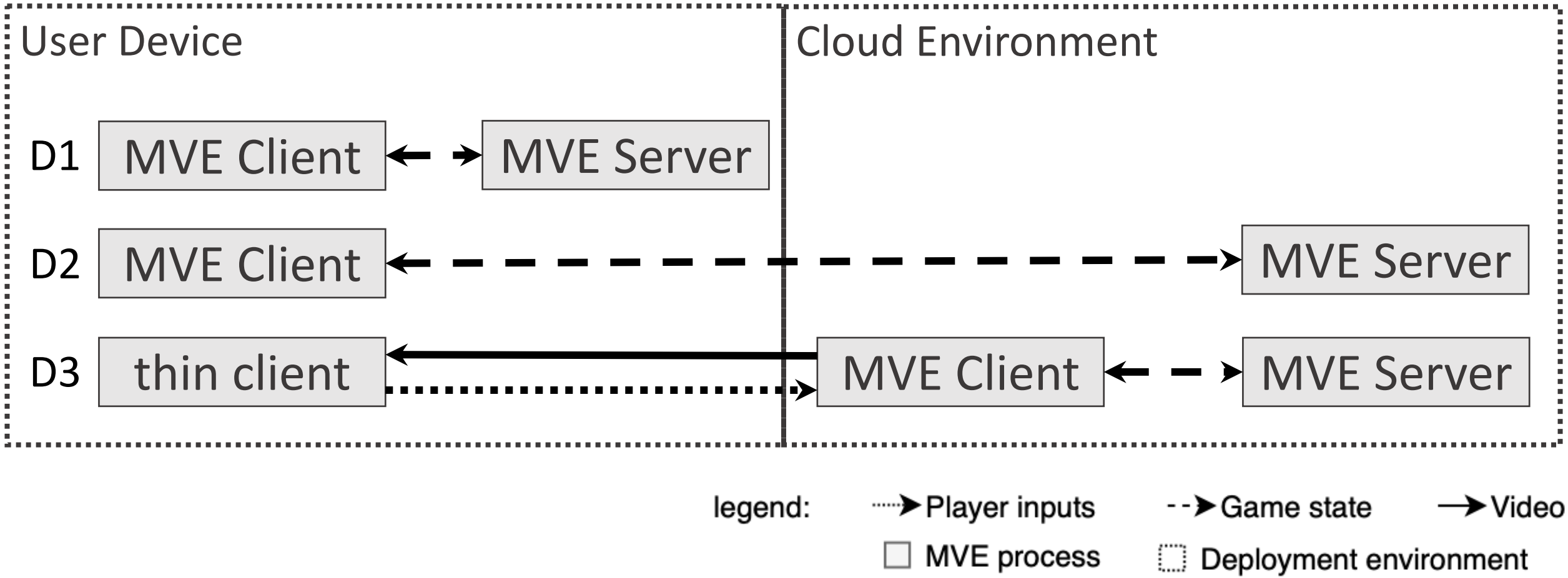
Inside a Modifiable Virtual Environment

MVEs typically use a clients/server architecture

The unique MVEs features are typically handled by the server

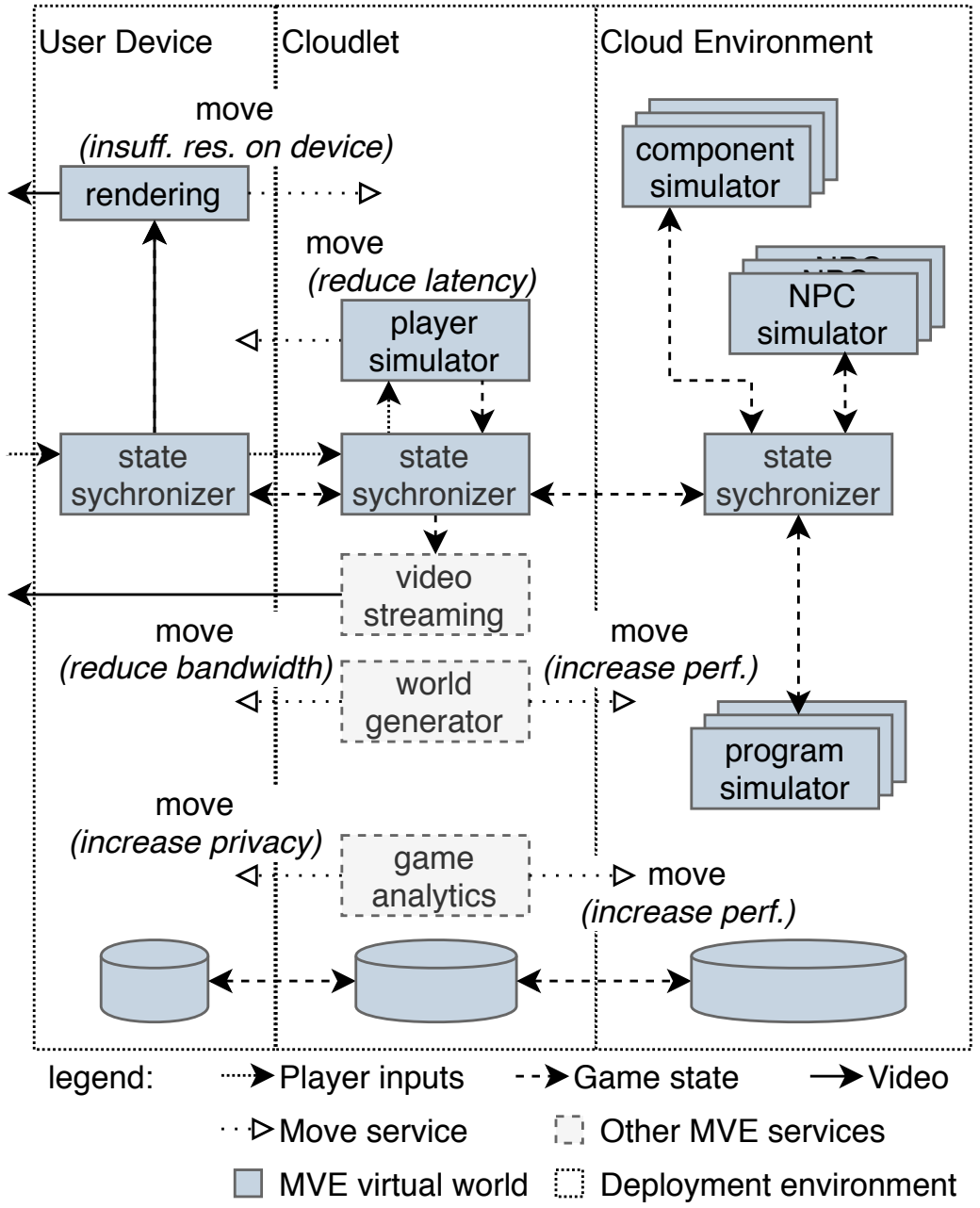


Deployment Models and Limitations



Vision for Large-Scale MVEs

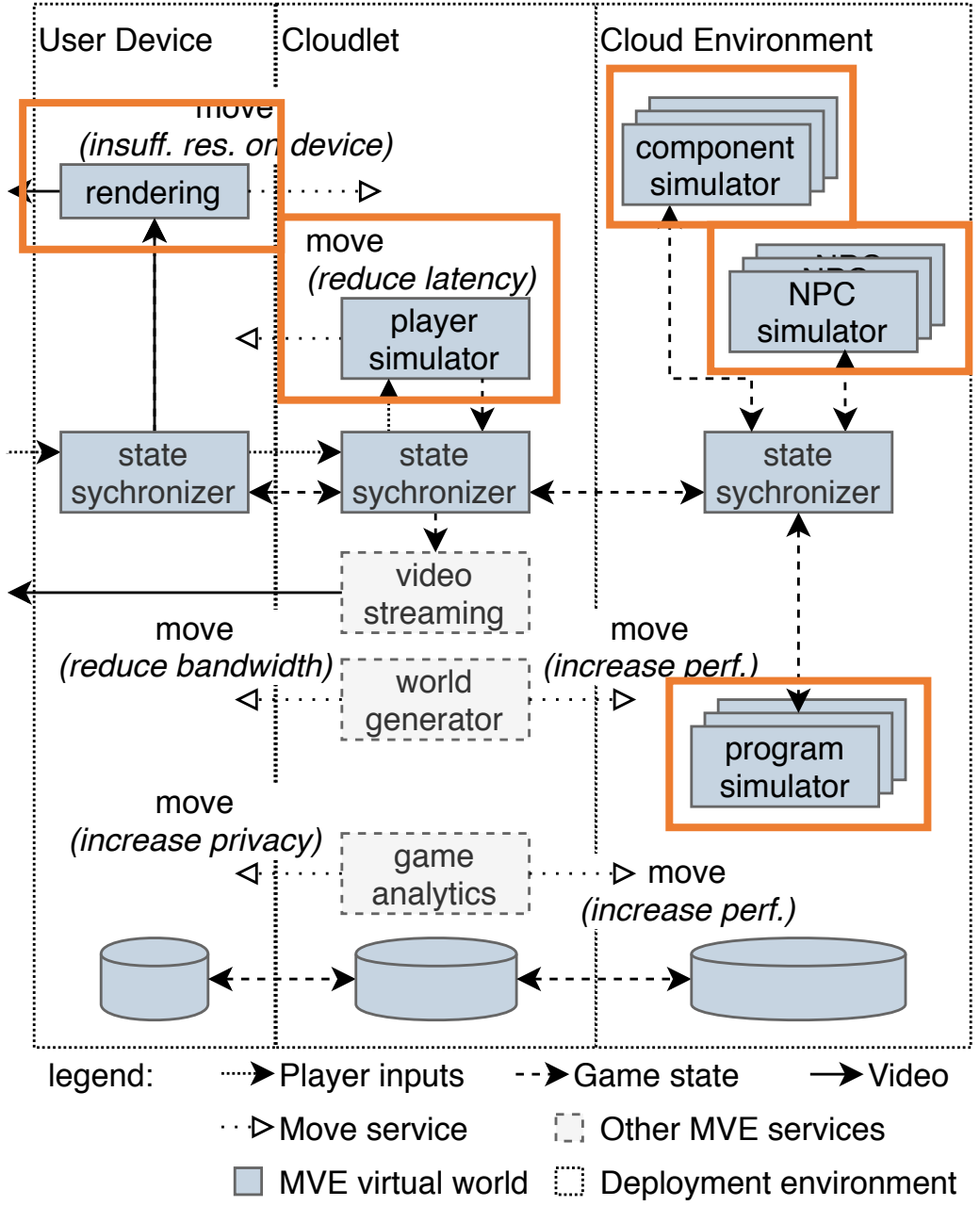
Minecraft-like games and, more generally, MVEs, will become cloud-based services scalable to millions of concurrent players (users).



Serverless Operation

- Operated professionally by the cloud operator
- Provisioned on-demand by the game developer or operator

- Independently scheduling services improves scalability and elasticity
- Increased modularity simplifies development



Specialized Consistency Models

- Quantify the amount of inconsistency in the system
- Use policies that selectively and temporarily allow inconsistencies in places where players are unlikely to notice

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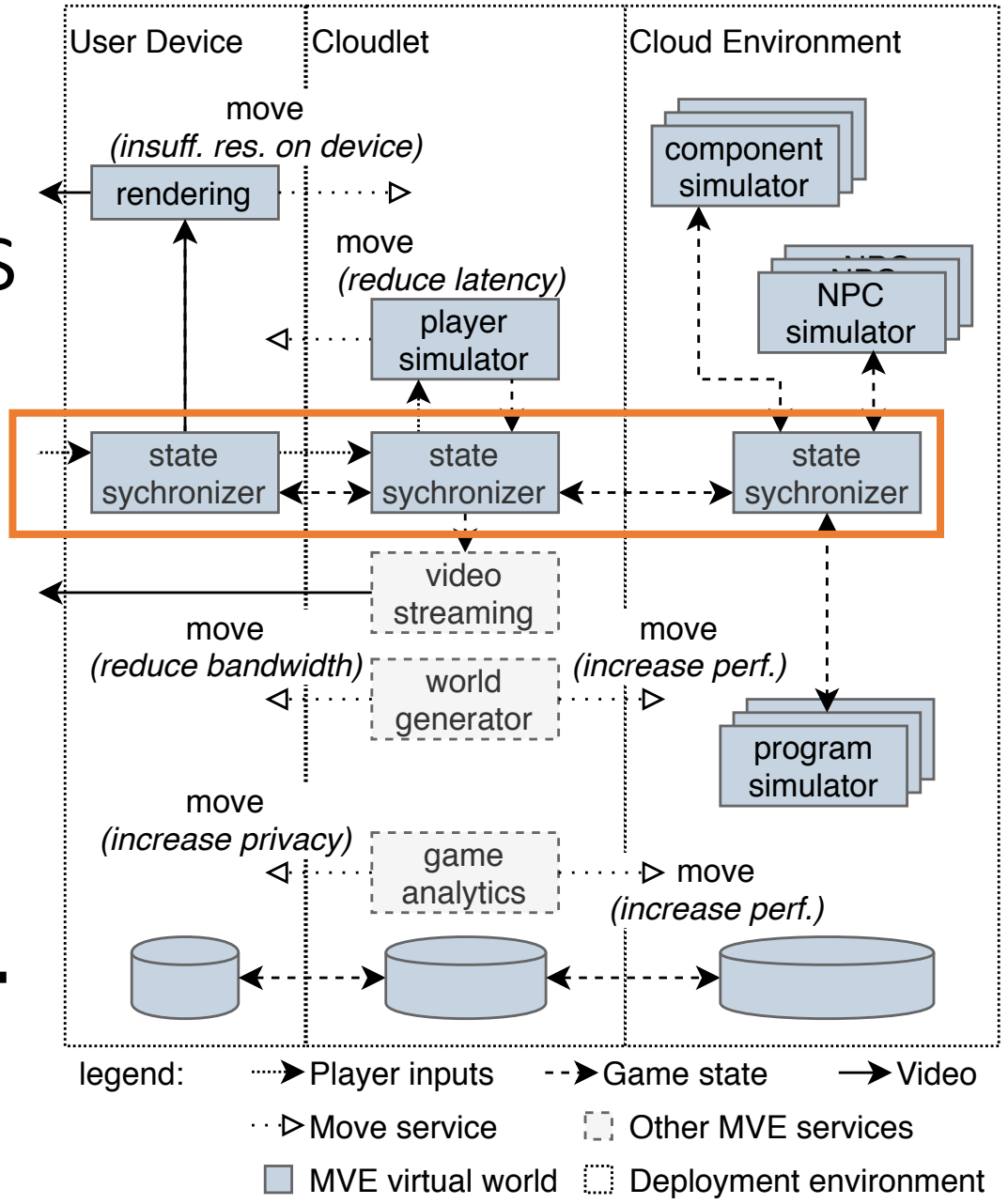
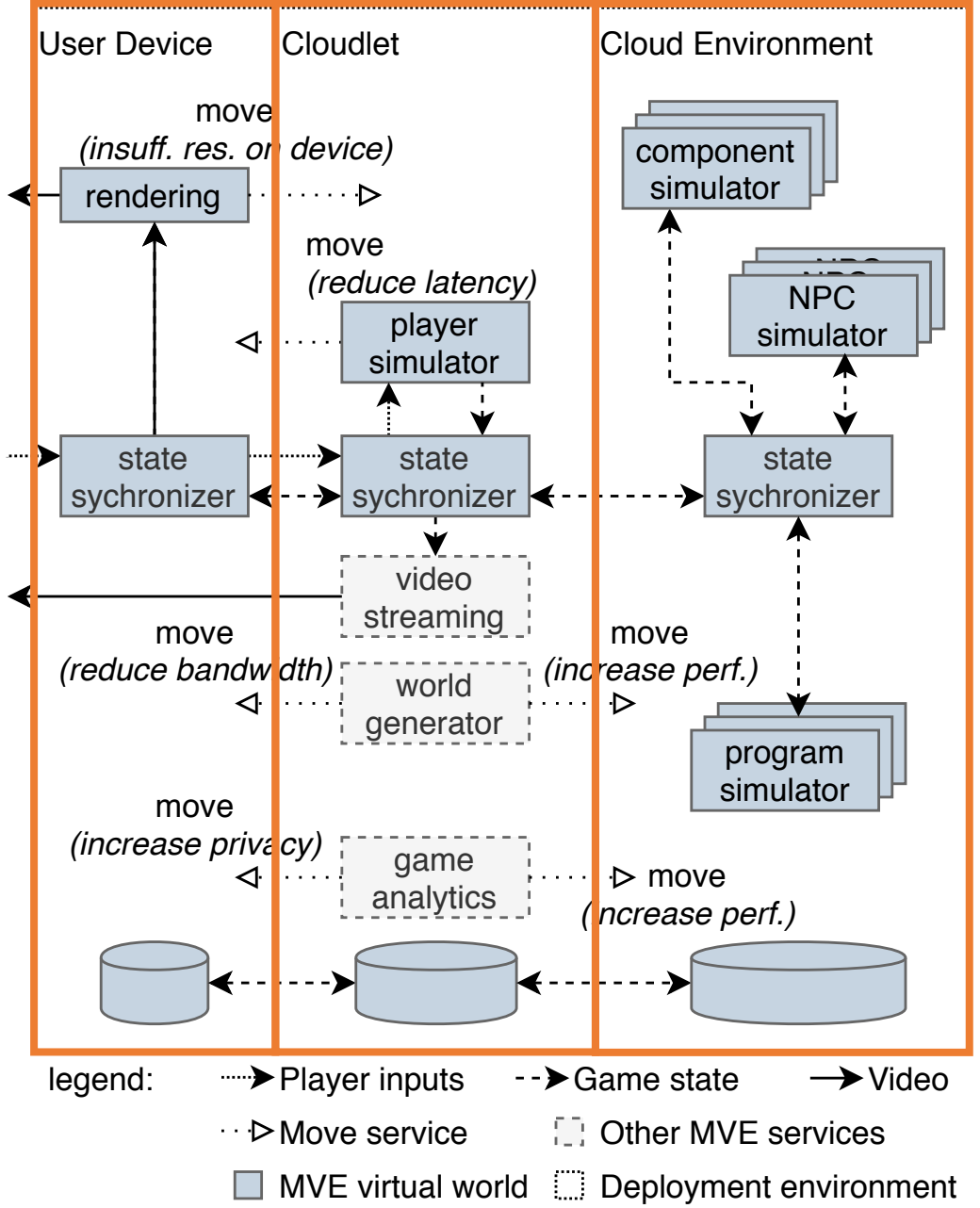
- Improve scalability without reducing player experience



Differentiated Deployment

- MVE services are deployed across user devices, clouds, and cloudlets, depending on available resources and QoS constraints.

- Support user devices with few resources
- Reduce load on the cloud and core network when possible



Future Research Areas

Towards Scalable, Cloud-Based MVEs

Serverless functions for independent scheduling of MVE services

Using existing serverless architectures for MVE-related services

- E.g., using PyWren,[1] Graphless[2] for game analytics

Supporting more complex MVE services

- E.g., generating terrain, simulators
- Guaranteeing non-functional properties
- Keeping (shared) state, communicating with other functions[3]

1: Jonas et al. Occupy the cloud: distributed computing for the 99%. SoCC ’17
2: Toader et al. Graphless: Toward Serverless Graph Processing. ISPDC’19
3: https://aws.amazon.com/blogs/aws/new-a-shared-file-system-for-your-lambda-functions/

Dynamic consistency units to control and limit MVE inconsistency

Quantifying and limiting inconsistency is possible using *consistency units*.[1]

How to adapt this model for MVEs?

- Real-time, interactive system
- Players joining and leaving; players creating and removing content
- Varying consistency requirements

1: Yu et al. Design and evaluation of a conit-based continuous consistency model for replicated services. TOCS'02

Schedule services at cloudlets to resources to improve QoS and cost

Using cloudlets for gaming looks promising

- Offloading,[1] rendering,[2] game analytics[3]

Supporting more MVE services

- Moving computational MVE services to the edge
- Concurrent rendering for gameplay broadcasting
- Efficient resource usage
- Storing and caching data

1: Dong et al. Computation Offloading for Mobile-Edge Computing with Multi-user. ICDCS'19
2: Lin et al. CloudFog: Leveraging Fog to Extend Cloud Gaming for Thin-Client MMOG with High Quality of Service. TDPS'17
3: Fu et al. EdgeWise: A Better Stream Processing Engine for the Edge. ATC'19

Take-Home Message

1. Modifiable Virtual Environments (MVEs) have more than 100 million users, and pose a *scalability challenge*
2. Our vision is to address this challenge by redesigning MVEs as serverless systems, in which MVE services …
    1. … are serverless
    2. … use specialized consistency models to exchange state
    3. … are deployed across user devices, cloudlets, and the cloud
3. These approaches show promise, and need to be explored further

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