XR Collaboration Architecture based on Decentralized Web
Contents

• Motivation
• Previous work
• Our approach
• Prototype implementation
• Conclusion
motivation
XR

XR
X = Variable

VR
Virtual Reality

MR
Mixed Reality

AR
Augmented Reality

oculus
Oculus Go
Facebook
October 11, 2017

Windows Mixed Reality Headsets
Microsoft
October 17, 2017

Hololens
Microsoft
March 30, 2016

ARKit iOS 11
Apple
September 19, 2017

ARCore
Google
August 29, 2017

What Are All These Realities? VR, MR, AR and XR 101, December 15, 2017,
https://www.achao.design/inspire/what-are-all-these-realities-vr-mr-ar-xr-101
Immersive Web

- WebXR
  - Through the browser
  - Cross platform

Immersive future of the web, December 7, 2018, Patryk Gułaś
https://arvrjourney.com/immersive-future-of-the-web-c416c1ac6e71
Decentralized Web (DWeb)

- Peer to Peer
- The next web, Web 3.0

![Diagram showing differents types of networks](image)

**Fig. 1**—(a) Centralized. (b) Decentralized. (c) Distributed networks.

On Distributed Communication Networks [Baran 1962]
Why the Web 3.0 Matters and you should know about it [Matteo Gianpietro Zago 2018]
Motivation

• Recently, XR based on the web has been grown to collaborate two or more users regardless of the user’s context.

• However, it still lacks the necessary collaboration architecture for practical situations which do not guarantee communication quality.

• To overcome the limitations of networking in practical environments, Availability of applications is required to be resilient to network latency and failure in web based XR collaboration.
Proposed method

• An XR collaboration architecture based on the decentralized web.
  o Synchronization
  o Offline first
  o Resiliency
previous work
XR based on Web

X3D scene access interface (SAI) API

- Interfaces to update an X3D scene rather than to handle user interaction

Frameworks and libraries

- libraries to create XR scene on the web much easier
XR for Multiple users

Social VR [Facebook 2016]

Monopoly AR [jolamux 2016]

VRChat [VRChat 2017]

Guns of Boom [Game Insight 2018]
Need for Decentralized Web

HTTP is inefficient and expensive

 Humanity’s history is deleted daily

The web’s centralization limits opportunity

Our apps are addicted to the backbone

Ipfs.io, The web of tomorrow needs IPFS today,
Kien Nguyen, A P2P VIDEO DELIVERY NETWORK (P2P-VDN)
Need for Decentralized Web

[Singhal and Zyda 1999]

- Elimination of centralized point for data access
- Scalability
- Fault Tolerance
Decentralized Database (DDB)

GunDB [Nadal 2016]

- P2P database that could survive living inside any browser, and could correctly sync data between any device after assuming any offline-first activity.

OrbitDB [Haadcode 2016]

- serverless, distributed, peer-to-peer database using IPFS as its data storage.
CRDT: Conflict-free replicated data type

- **Operation-based CRDTs**
  - commutative

- **State-based CRDTs**
  - convergent
our approach
Extensions of common shared space

- Base Data
- Derived data
Publish / Subscribe among peers

- **No server**
  - No request and response
- **Publish then subscribe**

- Any peer can be a publisher and a subscriber according to interests
Publish side

• Data state
• Application state
• Scene graph state

```javascript
{
  id: 'gift',
  tagName: 'a-box',
  parent: 'a-scene',
  attributes:
    position: { x: 0, y: 0, z: 0 },
    rotation: { x: 0, y: 45, z: 45 },
    scale: { x: 1, y: 1, z: 1 },
    color: 'red',
    'transform-controls': { activated: false },
}
```
Subscribe side

- Which state
  - Application state vs Scene Graph state
- Which case
  - Updating the space vs Initializing the space
Subscribe side - state

• Which state
  o Application state vs Scene Graph state
  o Which state is the data from?
Subscribe side - case

- Which case
  - Updating the scene
    - As soon as possible
  - Initializing the scene
    - Assets → entities
    - Parent → children

```html
<a-scene>
  <a-assets>
    <a-asset-item id="ball-obj" scr="ball.obj"></a-asset-item>
    <a-asset-item id="ball-mtl" scr="ball.mtl"></a-asset-item>
  </a-assets>
  <a-box id='gift' position="x:0; y:0; z:0" rotation="x:0; y:45; z:45" scale="x:1; y:1; z:1" color="red" transform-controls="activated: false"></a-box>
  <a-entity id="valve">
    <a-entity id="pipe">
      <a-cylinder id="pipe-up"></a-cylinder>
      <a-cylinder id="pipe-down"></a-cylinder>
    </a-entity>
  </a-entity>
  <a-entity id="ball" obj-model="obj: #ball-obj; mtl: #ball-mtl"></a-entity>
</a-scene>
```
Subscribe side

- Derived data
  - What makes difference in each Extension
  - Environments, user information, interaction
prototype implementation
Overview Decentralized WebXR

• BASE: Basically Available, Soft State, Eventual Consistency
Local update from Derived data

- Environments
- Camera’s rotation of each Extension
Synchronization

- Grey cover’s position
- User 1 publishes and all users (including publisher) subscribe to it
BASE

• Basically Available, Soft state, Eventual consistency
  ↔ ACID : Atomicity, Consistency, Isolation, Durability

• Offline-first

• Resiliency
Basically Available : Offline-first

- Connected peers still works.
- The offline peer is not synchronized, but still available
Basically Available: Resiliency

- Both cover and handle are updated
- Without one-way overwriting
Mesoscale Collaboration

- Collaborative interaction for multiple users in open place
- Scalability
conclusion
Summary & Future work

• We propose an XR collaboration architecture based on decentralized web for practical collaboration environments in the absence of a reliable network connection.

• We will continue developing our proposed method to improve usability.
thank you

This work was supported by the National Research Council of Science & Technology (NST) grant by the Korea government (MSIT) (No. CMP-16 01-KIST).
This work was supported by the National Research Council of Science & Technology (NST) grant by the Korea government (MSIT) (No. CMP-16 01-KIST).
https://d.wxrx.onl/web3d

• macOS - Chrome, Safari, Firefox
• Windows - Chrome, Edge, Firefox
• android - *Chrome, Firefox
• iOS - *Chrome, **Safari, Firefox

* Setting 1
  o Open 🌎 Chrome
  o Type chrome://flags
  o Search Generic Sensor
  o Default → Enabled

** Setting 2
  o Open 🔄 Settings
  o Select 🍎 Safari
  o Enable Motion & Orientation Access
thank you

This work was supported by the National Research Council of Science & Technology (NST) grant by the Korea government (MSIT) (No. CMP-16 01-KIST).
CAP theorem

• Distributed data store
• Impossible to simultaneously provide more than two
  o Consistency
  o Availability
  o Partition tolerance

• DWXRX is AP system with eventual consistency
Eventual Consistency

• **Strong consistency**
  - All write operations are done strictly sequentially
  - Read request on any replicas returns the same
  - A real-time consensus is required

• **Eventual consistency**
  - Make updates on the local, then propagate updates
  - Read on some replicas can return obsolete state
  - Rollback or somehow decide what to do in case of conflicts
  - We still need consensus, but not in the real-time
Partial update

- **Interest Matching Algorithms**
  - Address the trade-off between runtime efficiency and filtering precision
  - Peers receive the minimal set of data that are of interest to them

- **Reduce conflicts**