THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY (GUANGZHOU)

Information-Centric Networking for Distributed AR/VR

IETF-115 Metaverse Side Meeting

Dirk Kutscher
2022-11-07

Social VR Platforms

Issues and Requirements

ACM IMC-2022

Are We Ready for Metaverse? A Measurement Study of Social Virtual Reality Platforms

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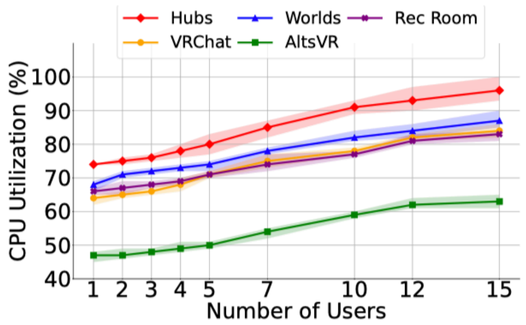
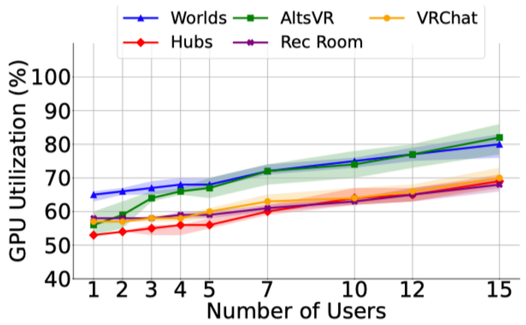
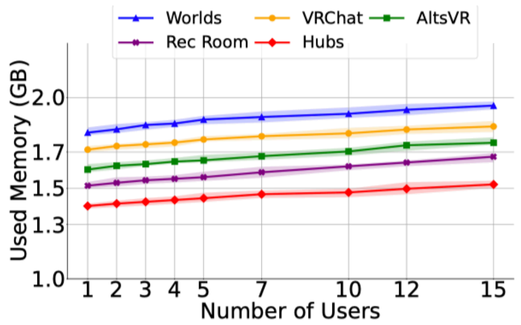
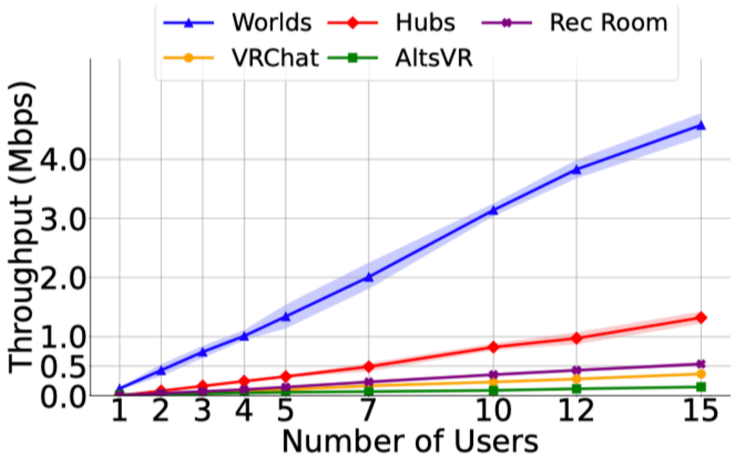
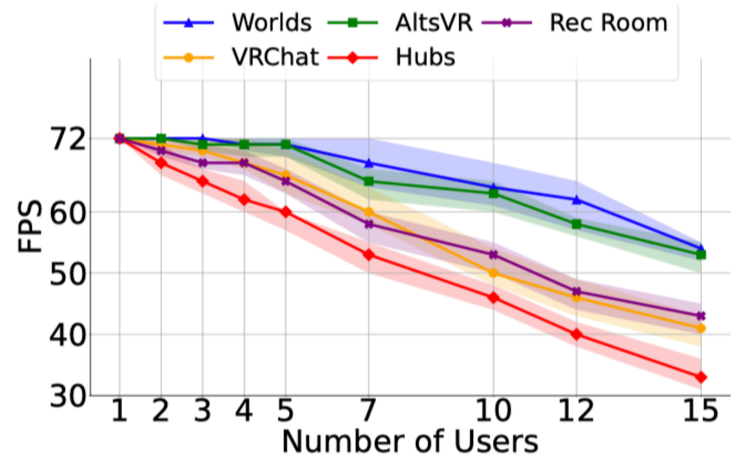
- **Study of AltspaceVR, Horizon Worlds, Mozilla Hubs, Rec Room, and VRChat**











Social VR Platforms

Findings

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- **Significant scalability issues with most platform even with smaller numbers of users**
  - Latency increase and throughput decrease (from server and network load)
  - CPU/GPU load increase from rendering complexity (many users, avatars)
- **Performance and CPU/GPU utilization quite susceptible to packet loss**
  - Different types of protocols, sometimes with some interaction

Social VR Platforms

Suggestions

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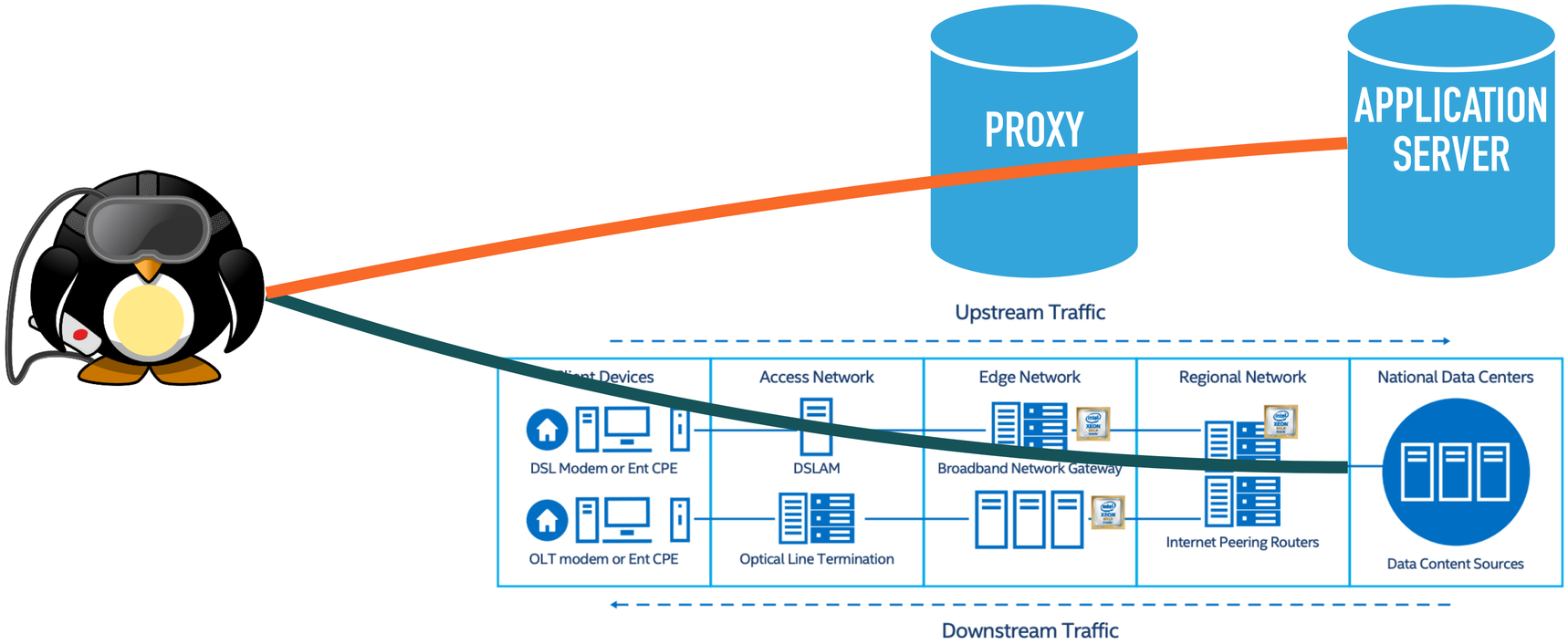
- **Multidestination communication capability**
  - For model data, events etc.
  - Offloading servers and networks
- **Optimal use of network and server resources**
  - Avoid server-mediated communication where not needed
- **In-Network computing support**
  - Offloading user devices through remote rendering and synthesizing

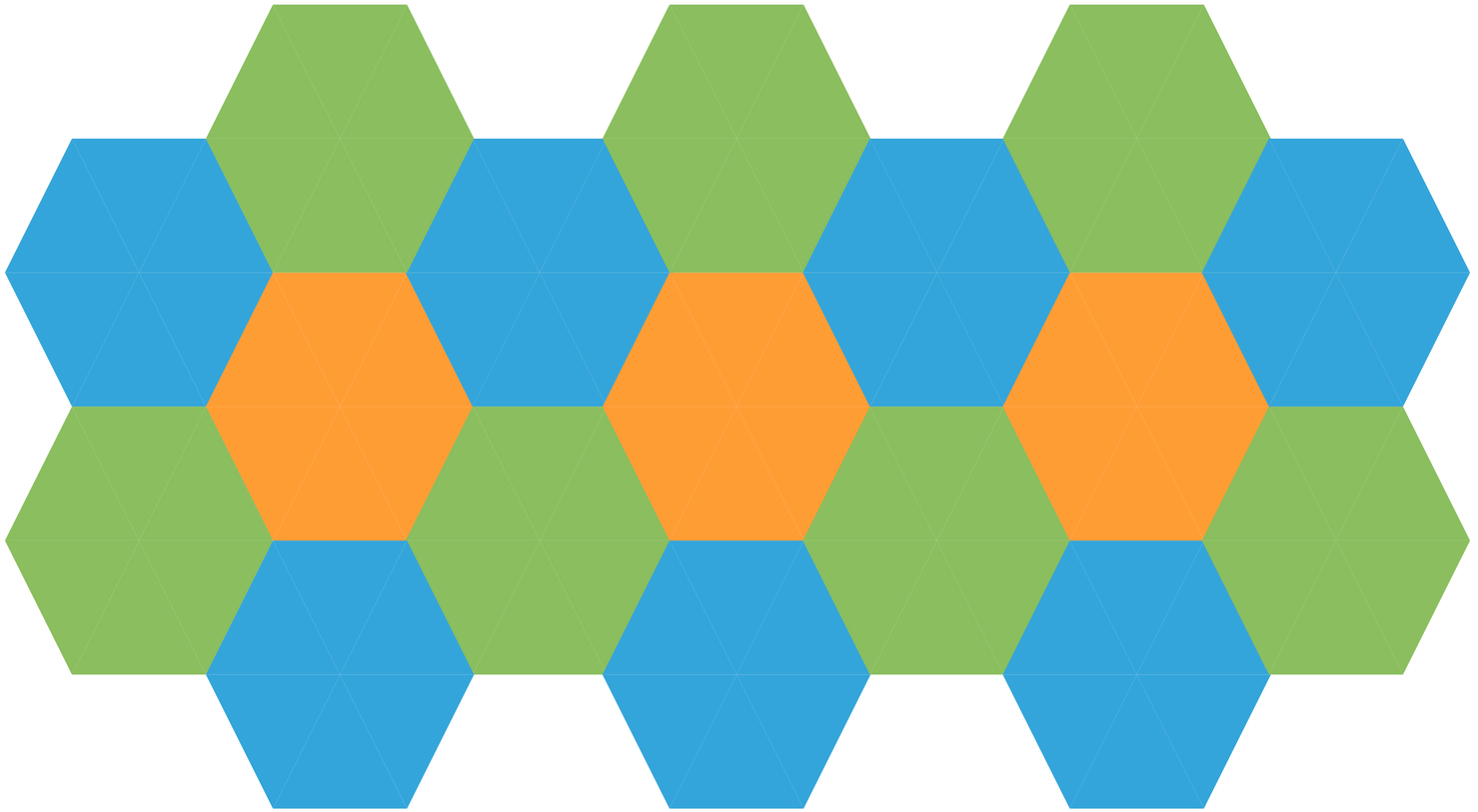
Distributed AR/VR

From Overlays...



Distributed AR/VR

... To Leveraging Networking and Computing Resources



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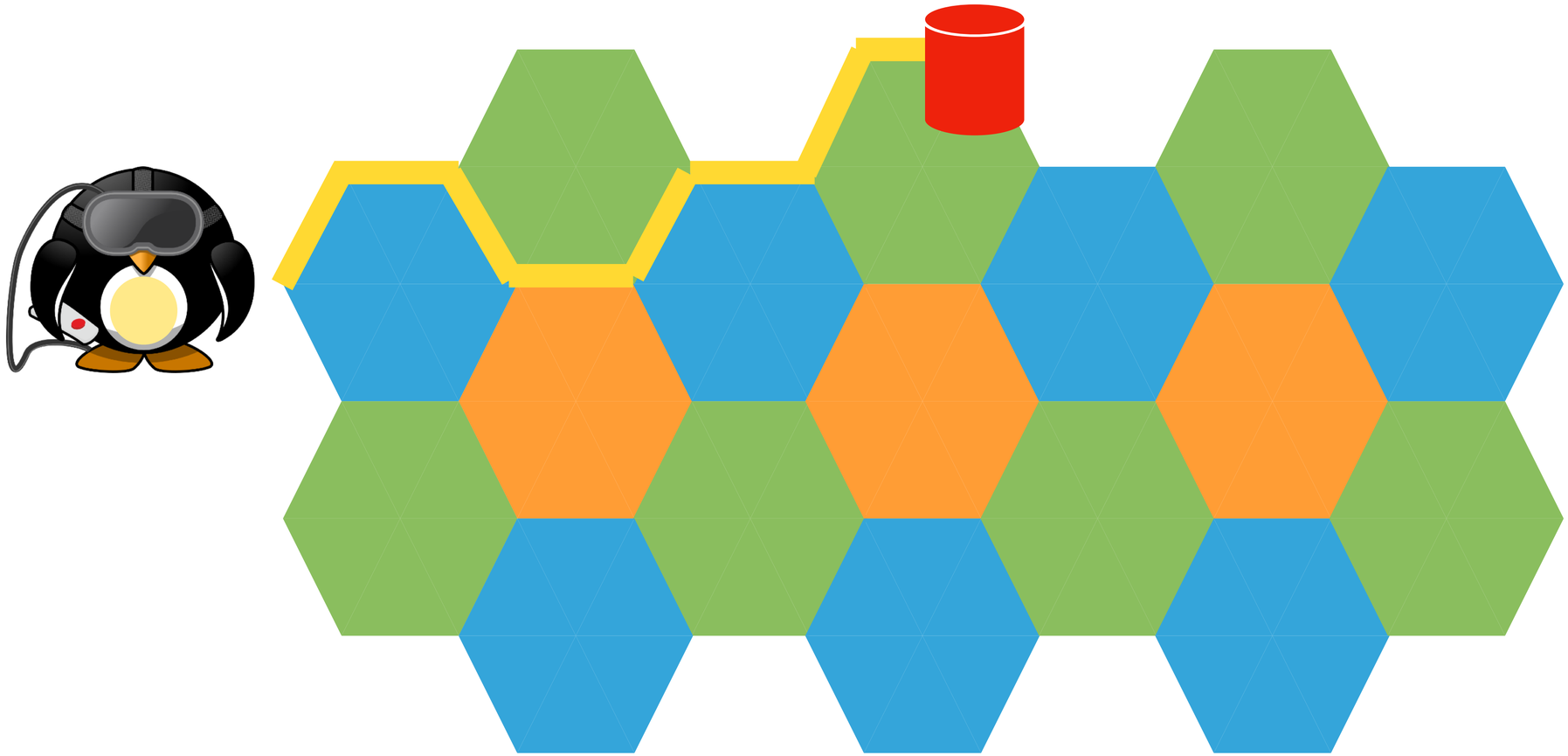

Distributed AR/VR

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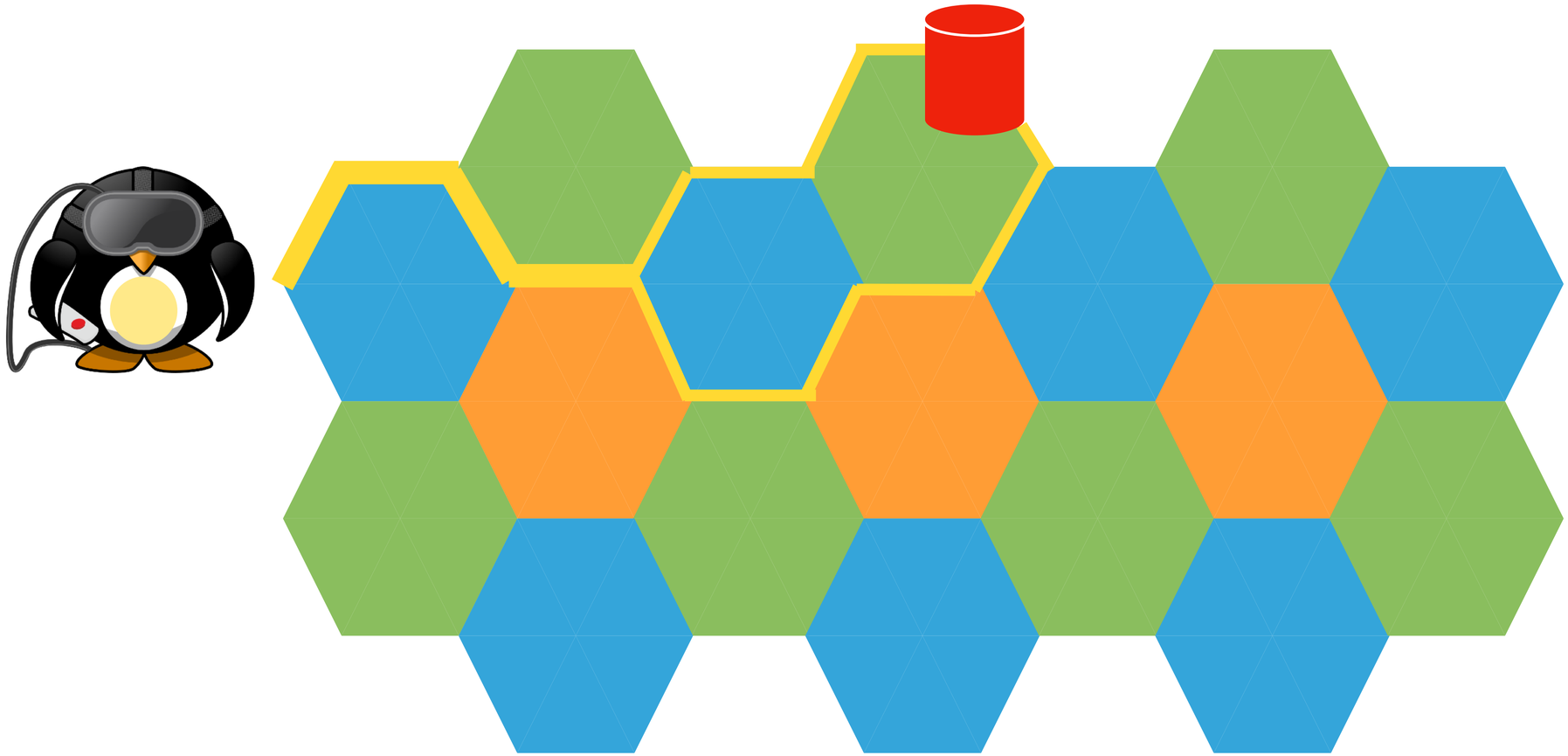

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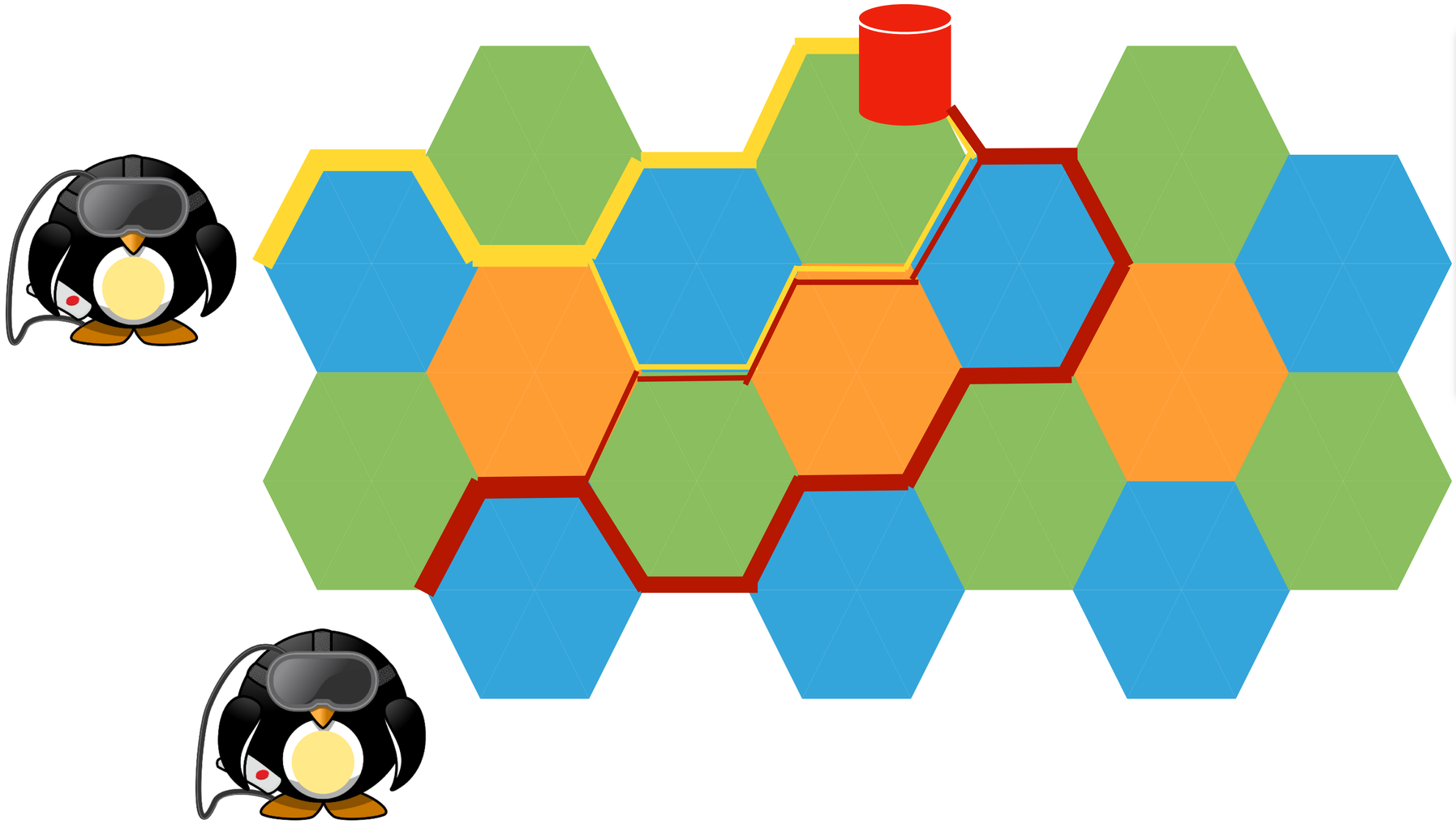
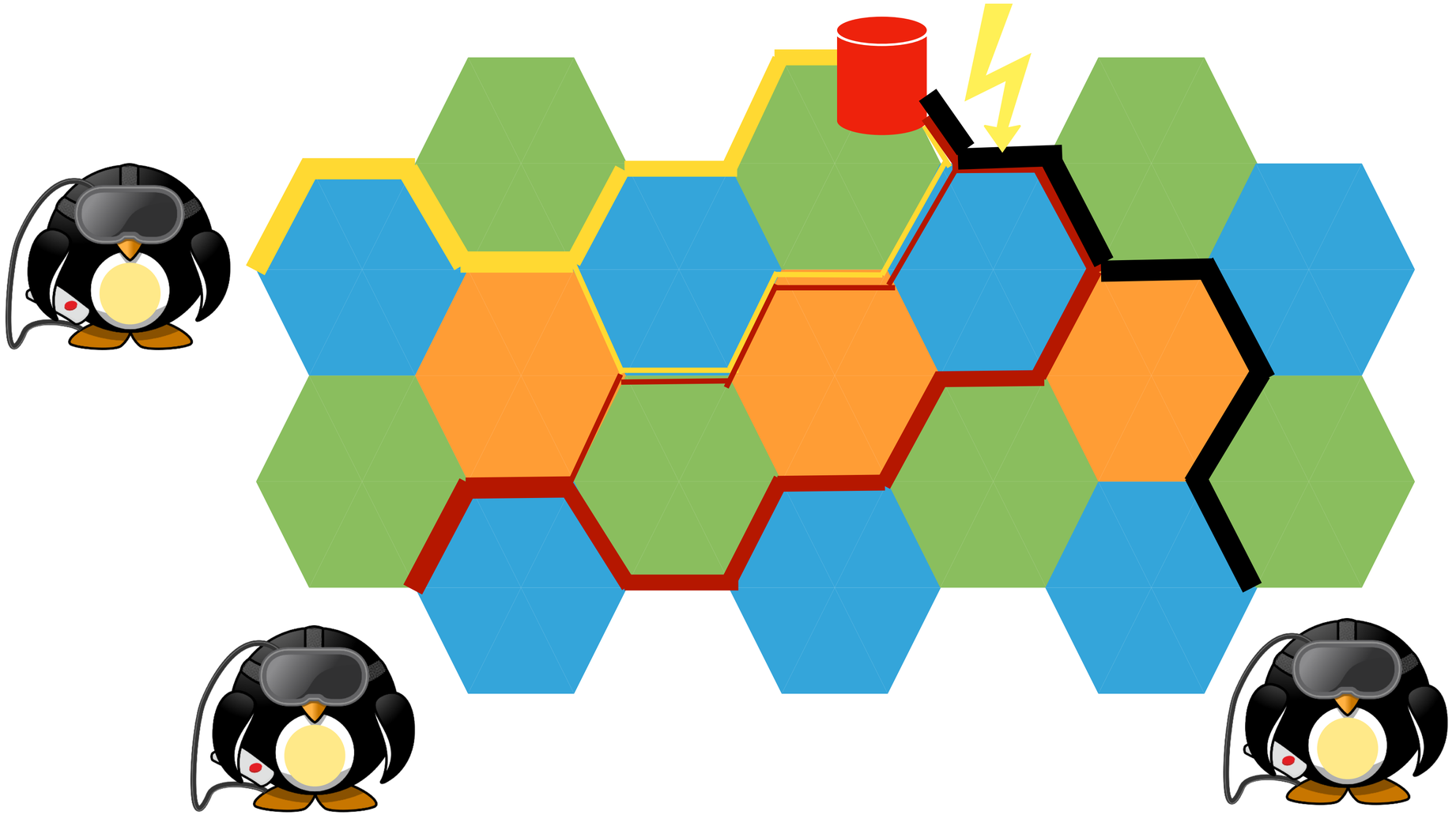


Leveraging in-network path diversity, dynamically

Distributed AR/VR

... To Leveraging Networking and Computing Resources



Distributed AR/VR

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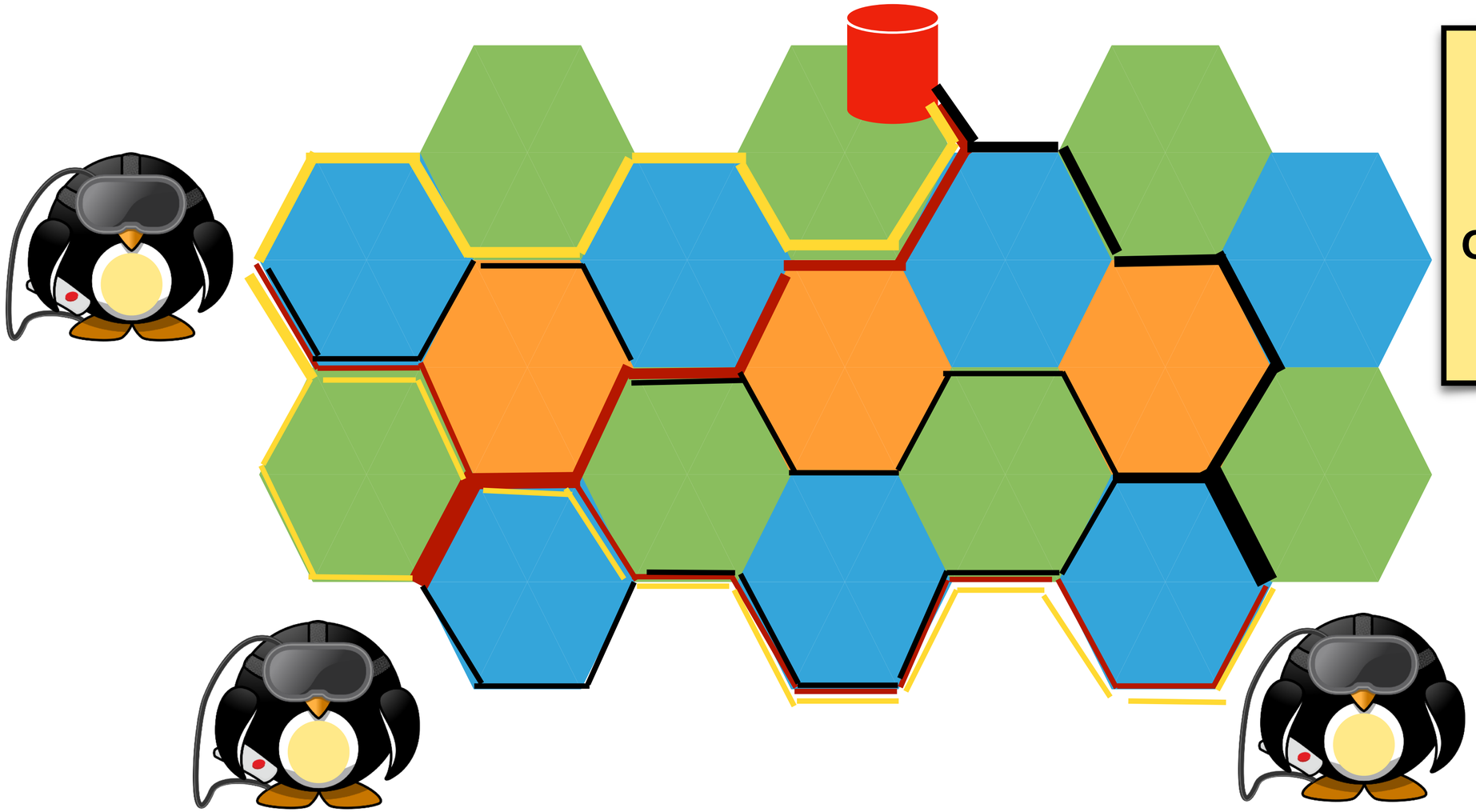

Direct communication

Distributed AR/VR

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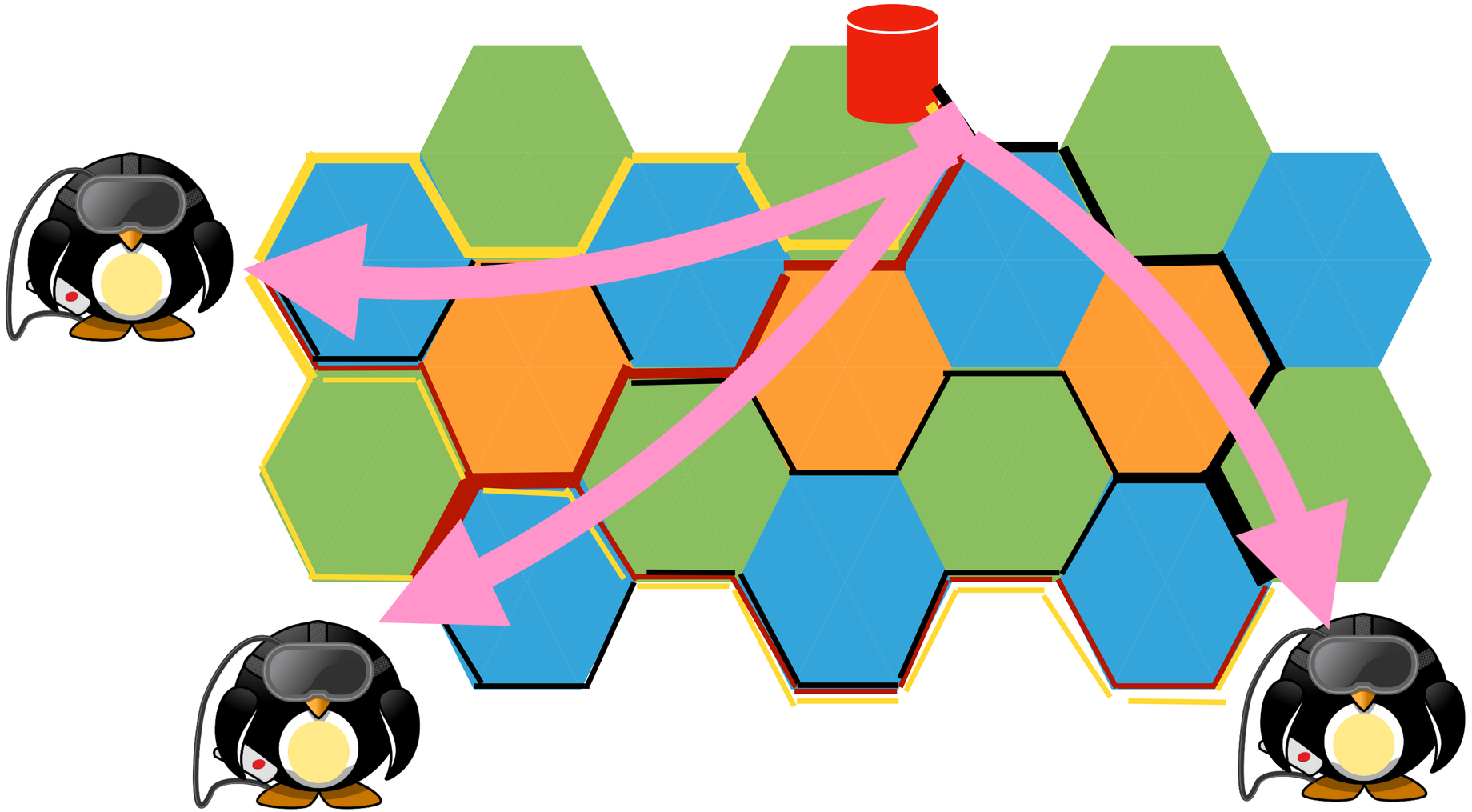

Distributed AR/VR

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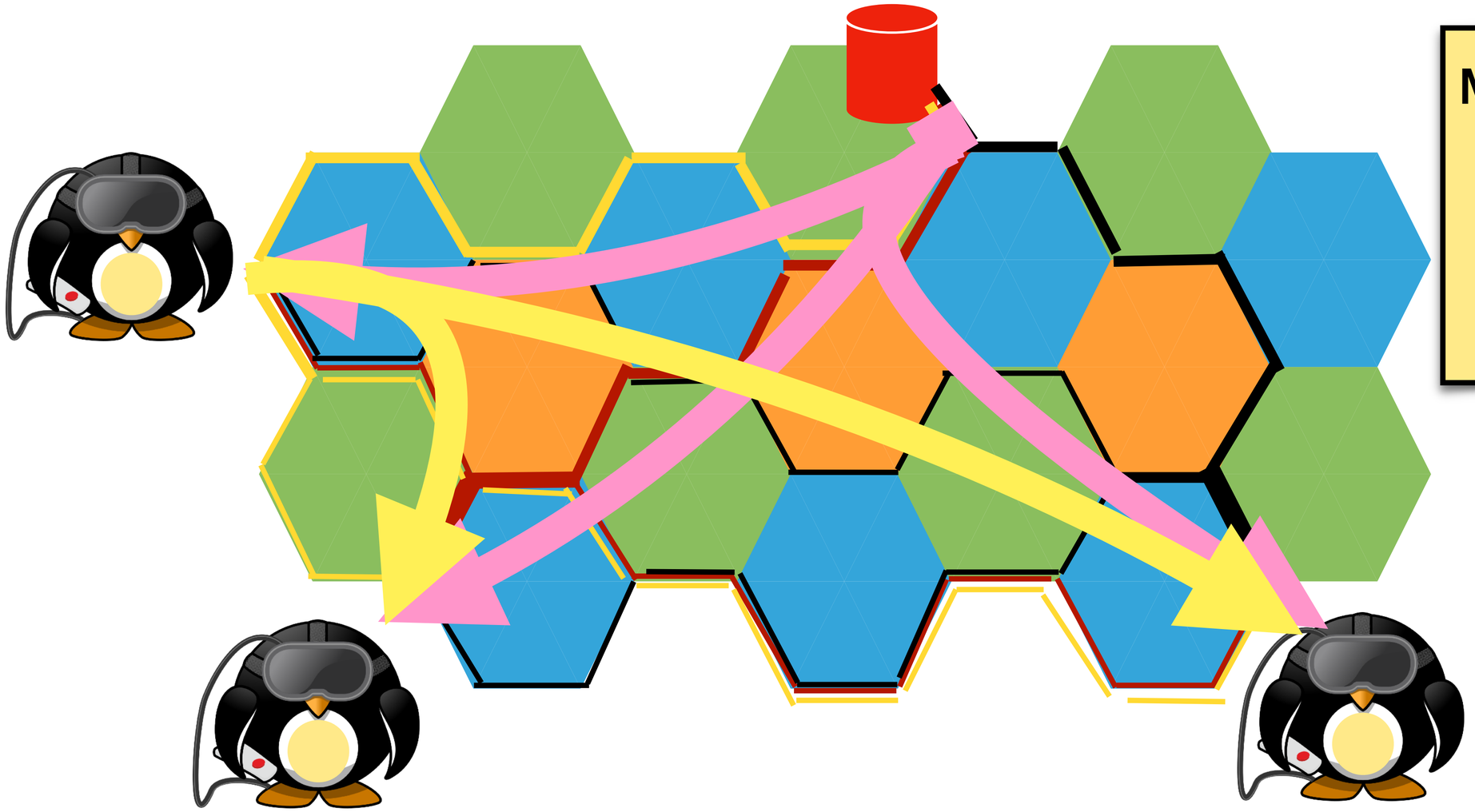

Multi-destination distribution for server and network offloading

Distributed AR/VR

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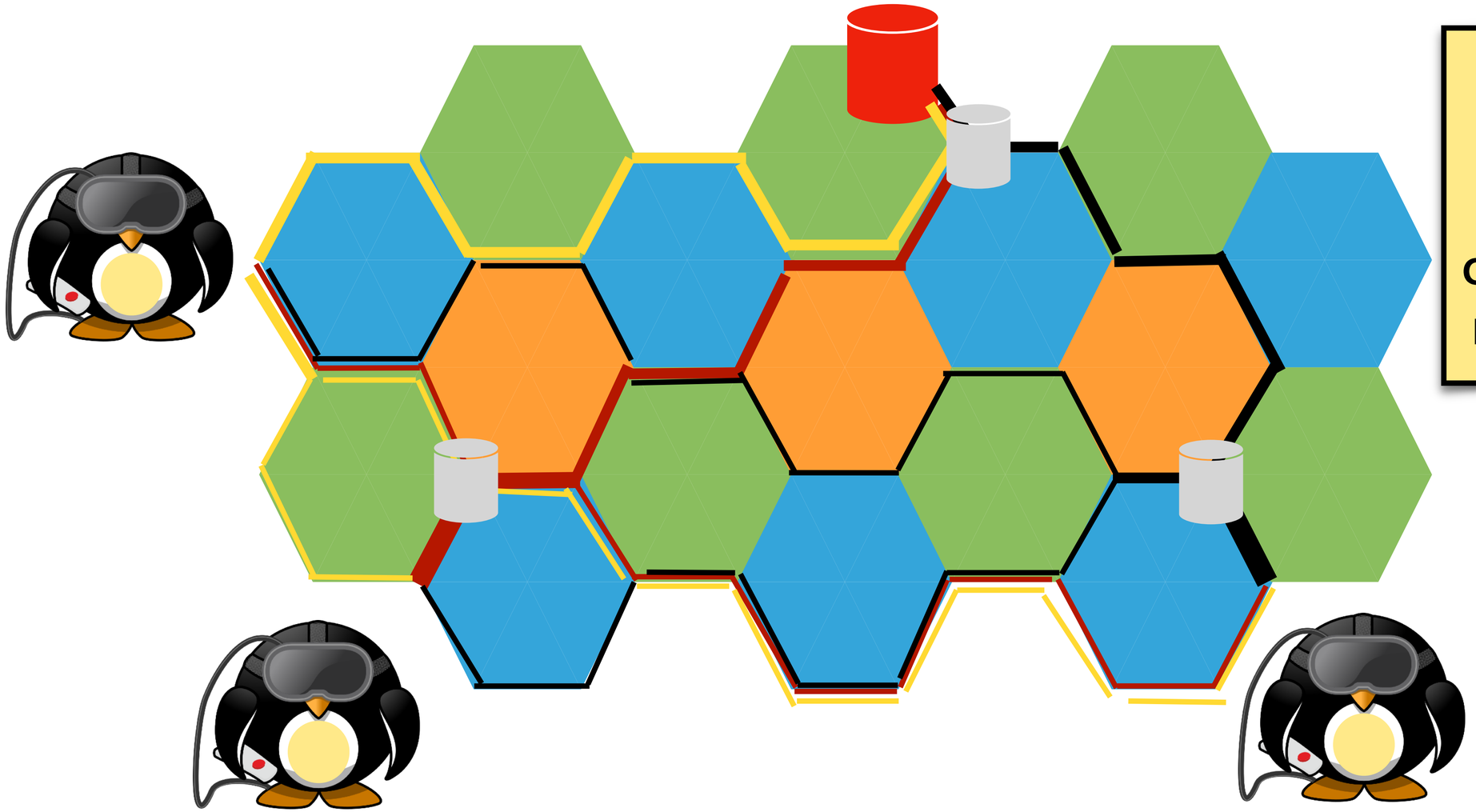
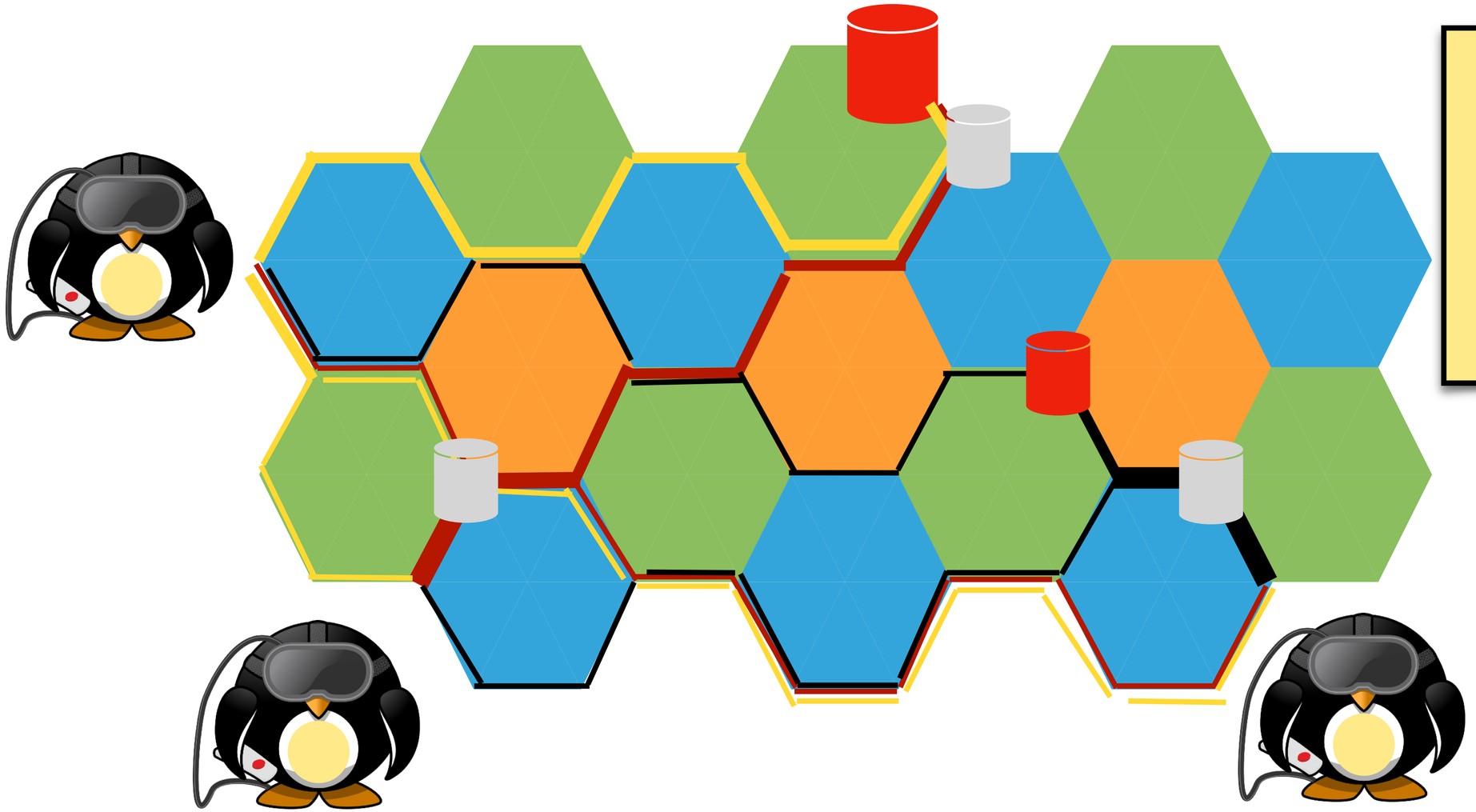


In-network caching for server/network offload and local retransmissions

Distributed AR/VR

... To Leveraging Networking and Computing Resources



In-network computing for offloading endpoints and the network

Distributed AR/VR

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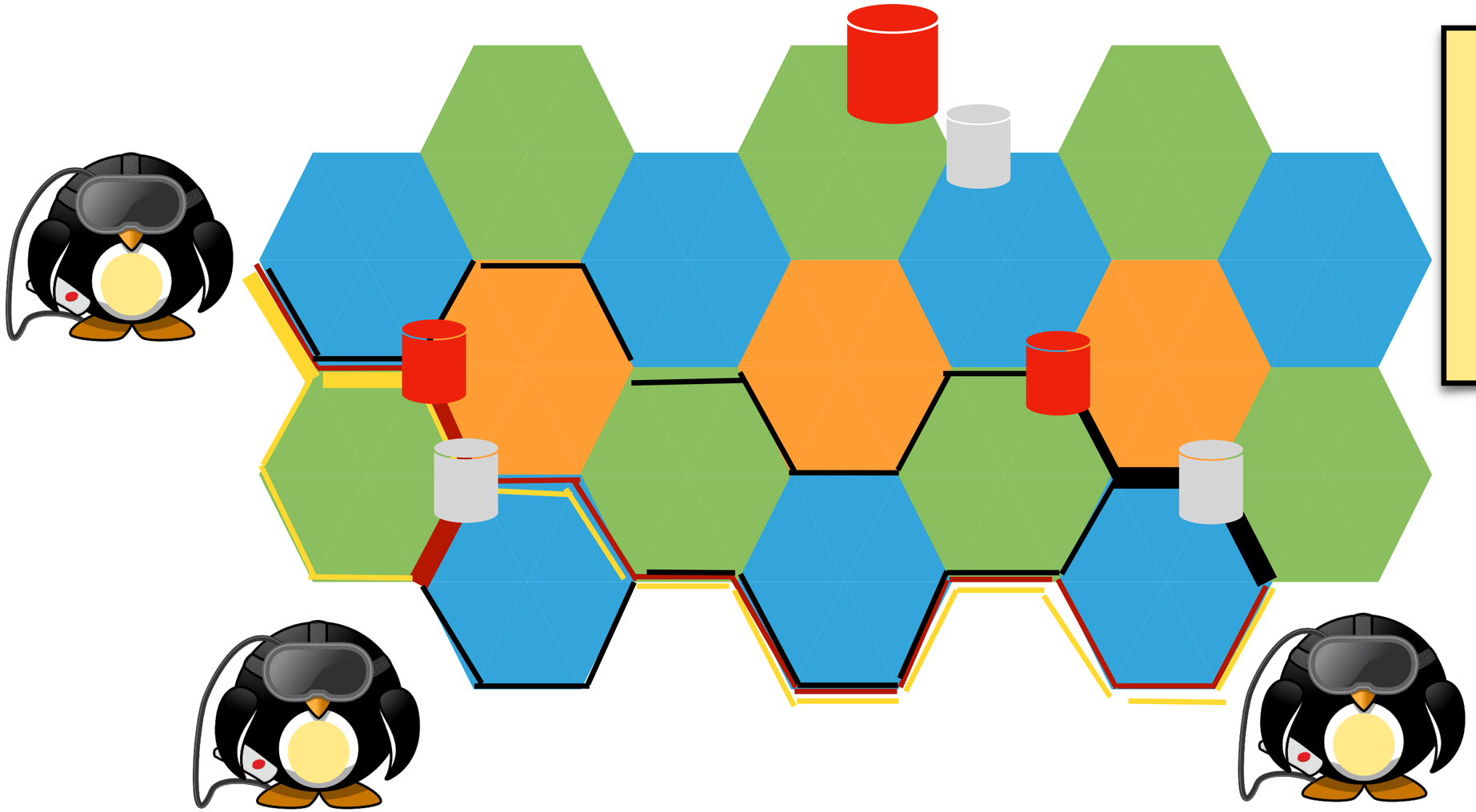

In-network computing for offloading endpoints and the network

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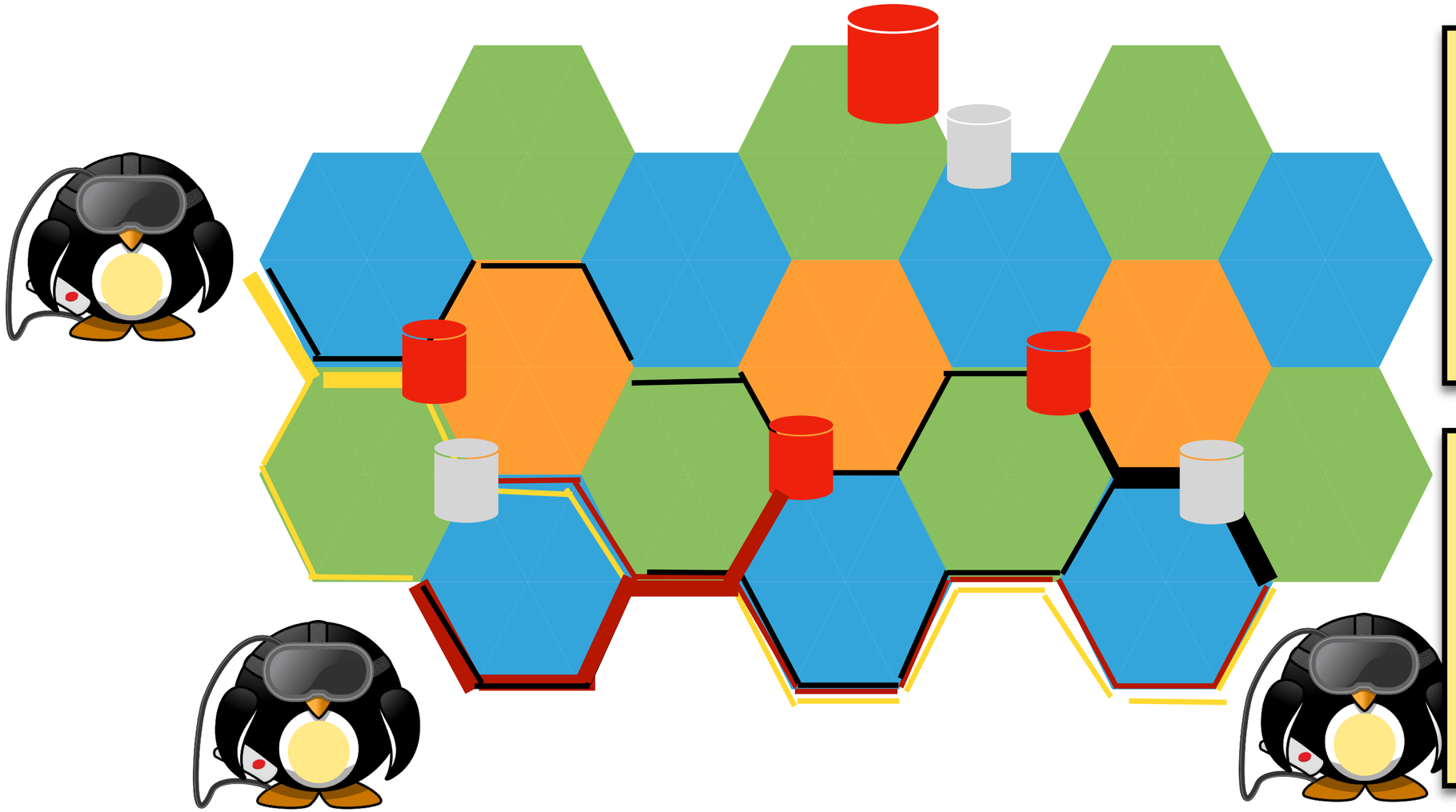


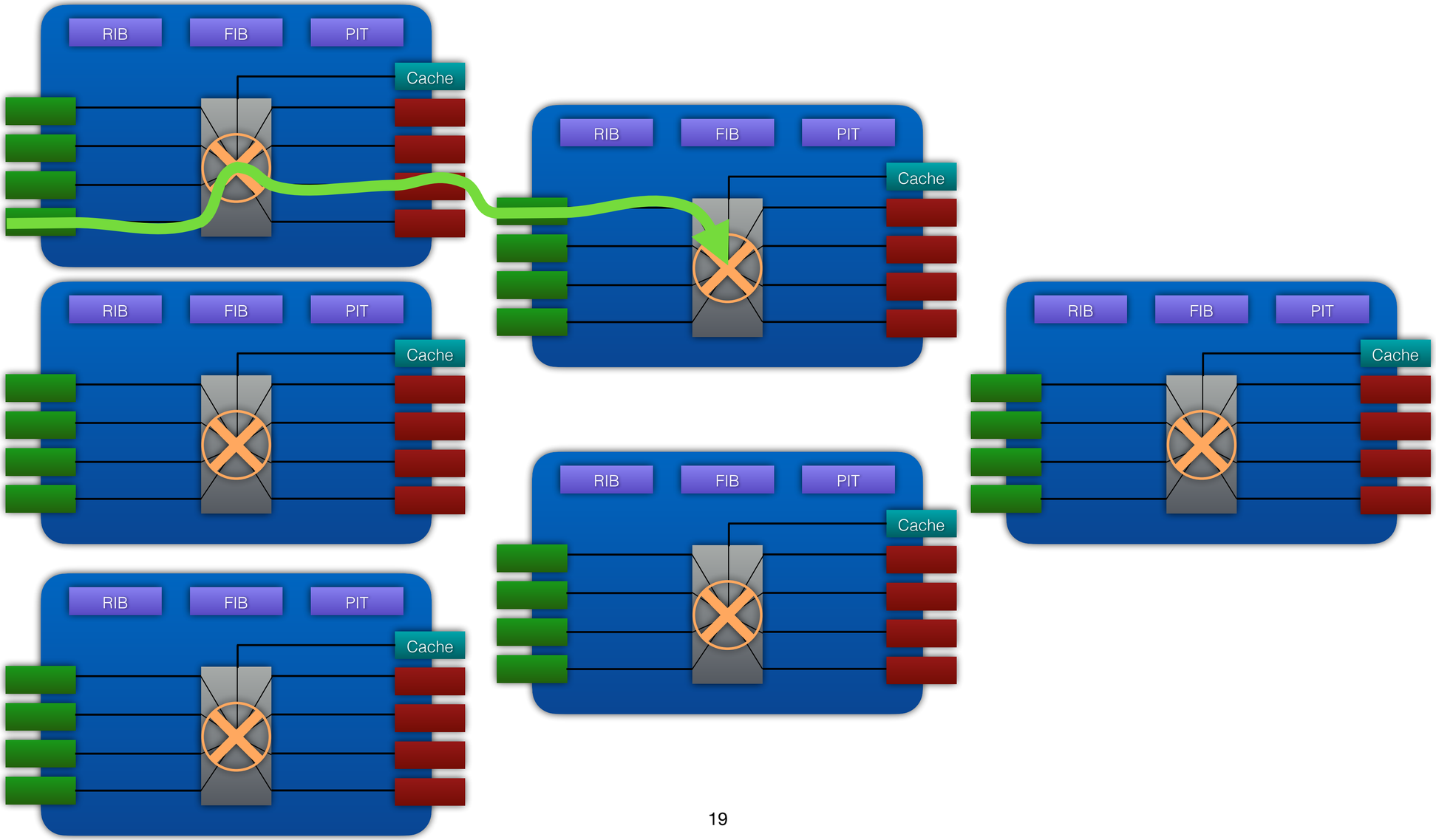
In-network computing for offloading endpoints and the network

with low-overhead adaptability for scaling and consolidation

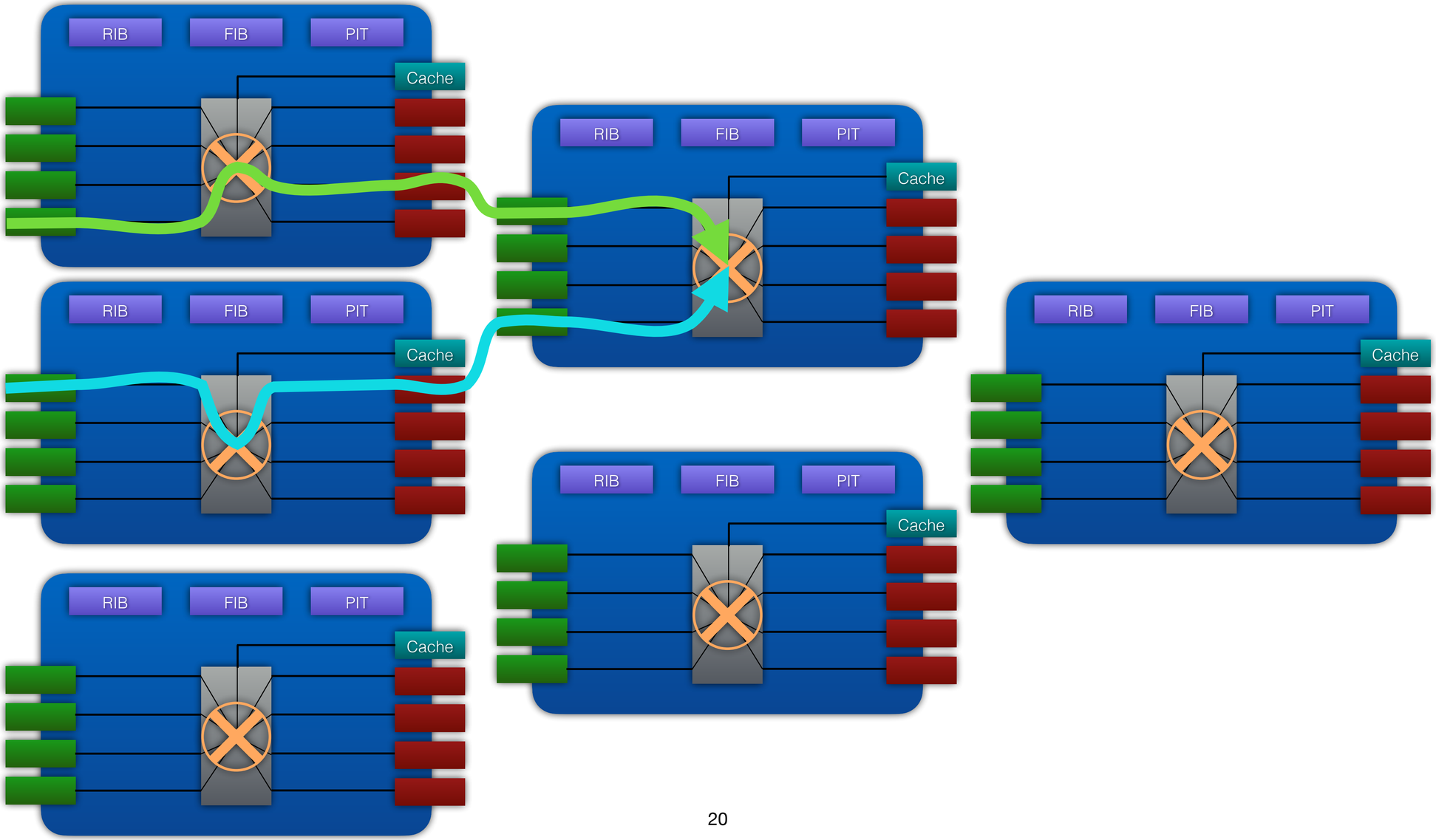
Better Forwarding Service Needed

- **Accessing named data securely**
  - Location-independence
  - Name-content binding and receiver-driven operation for preventing "unwanted traffic" attacks
- **More functionality in the network**
  - Stateful forwarding for enabling better load balancing, multi-path forwarding and multi-destination distribution
  - In-network caching, request aggregation for additional optimizations
- **Better support for in-network computing and managed caching**
  - Make it easier to instantiate, move, delete in-network computing
  - Leveraging Named-Data principle
- **Avoiding unnecessary centralization**
  - Don't exclude local-context social AR/VR
  - Standardize protocol semantics and the required underlay protocol instantiations, with room for innovation

ICN Empowered Forwarding Plan



ICN Empowered Forwarding Plan



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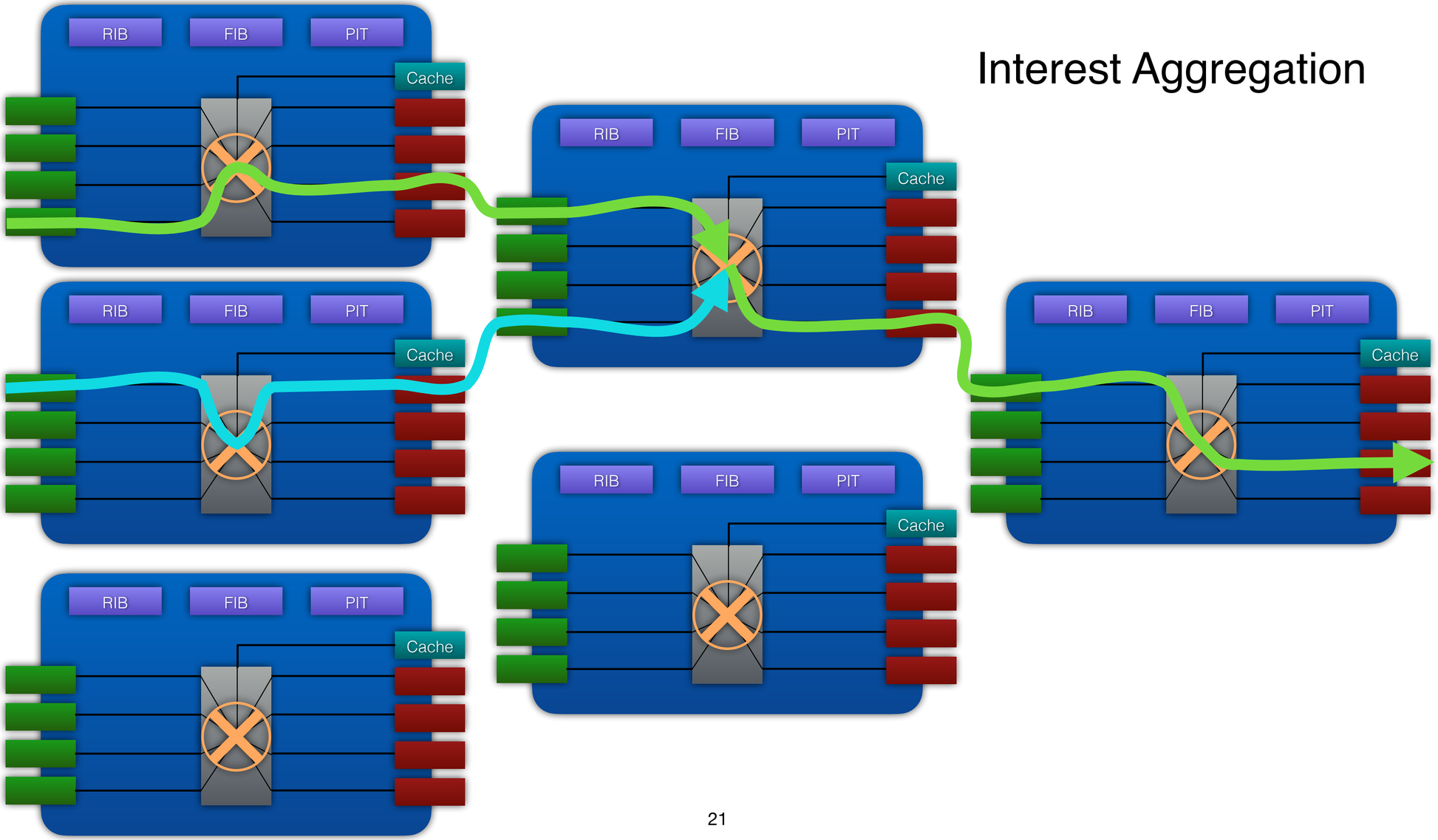
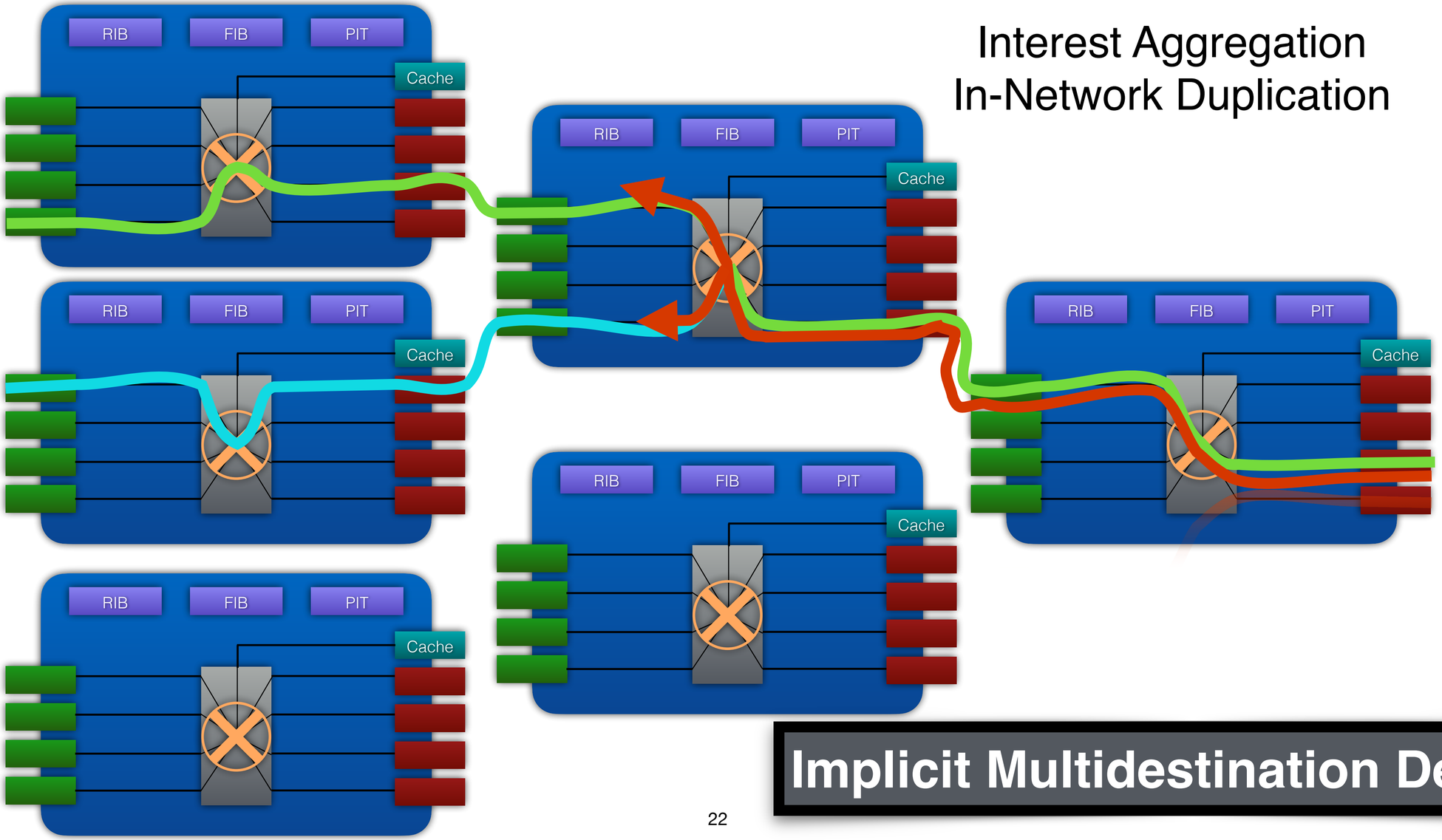


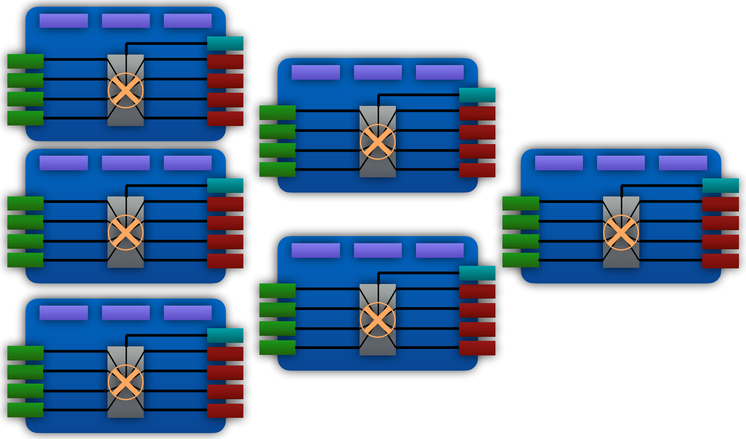
ICN Empowered Forwarding Plan



Interest Aggregation
In-Network Duplication

Implicit Multidestination Delivery

ICN Empowered Forwarding Plan



ICN Interest/Data
One communication primitive to support different interaction styles and distribution models

Interest Aggregation
In-Network Duplication

Implicit Multidestination Delivery

In-Network Latency Observations
Path Diversity

Load Balancing

In-Network Latency & Loss Observations
Pending Interest State

In-Network Retransmissions

ICN – at which Layer?

- **ICN principles could be implemented at application layer**
  - HTTP, MoQ & QuicR, IPFS etc.
  - Research and experimentation experience has shown that you want to do better
- **Better not prevent packet-level operation**
  - Access to **authenticated** Named Data in the packet layer
  - More fine-granular resource control, load-balancing, multi-destination transfer
  - Can leverage specific underlay capabilities, e.g., wireless broadcast and QoS mechanisms
  - Can still aggregate smaller data units through manifests
- **ICN systems leverage multiple underlays already**
  - Ethernet, IP, UDP, TCP, Websockets, LoRa, TCP/IP embedding (Hybrid ICN)
  - Common forwarding semantics and packet formats with underlay-specific implementations

Relevant ICN Tech, Previous Work, and Opportunities

That you do not want to miss...

- **Multipath congestion control schemes**
- **Caching robustness and optimizations**
- **DASH over ICN**
- **Quality of Service**
  - Leveraging empowered forwarding model and more expressive naming could finally give us a handle on meaningful QoS
- **Other interactions than just RPC-style fetch and streaming**
  - Distributed dataset synchronization with Pub/Sub APIs
  - Robust interaction with compute servers and in-network computing

Optimal Multipath Congestion Control and Request Forwarding in Information-Centric Networks

Giovanna Carofiglio*, Massimo Gallo*, Luca Muscariello†, Michele Papalini‡,* Sen Wang§,*
* Bell Labs, Alcatel-Lucent, † Orange Labs, France Telecom, ‡ University of Lugano § Tsinghua University.

MIRCC: Multipath-aware ICN Rate-based Congestion Control

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A lightweight mechanism for detection of cache pollution attacks in named data networking

Mauro Conti[a,*], Paolo Gasti[b], Marco Teoli[a]

Internet Research Task Force (IRTF) D. Oran
Request for Comments: 9064 Network Systems Research and Design
Category: Informational June 2021
ISSN: 2070-1721

Considerations in the Development of a QoS Architecture for CCNx-Like Information-Centric Networking Protocols

SoK: The Evolution of Distributed Dataset Synchronization Solutions in NDN

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On Cache-Aware Dynamic Adaptive Streaming over Information-Centric Networking

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Toru Hasegawa

Named Tiles for Viewport-adaptive 360-Degree Video

Buffer Based Adaptation Using Scalable Video Coding for 360-Degree Video Streaming over NDN

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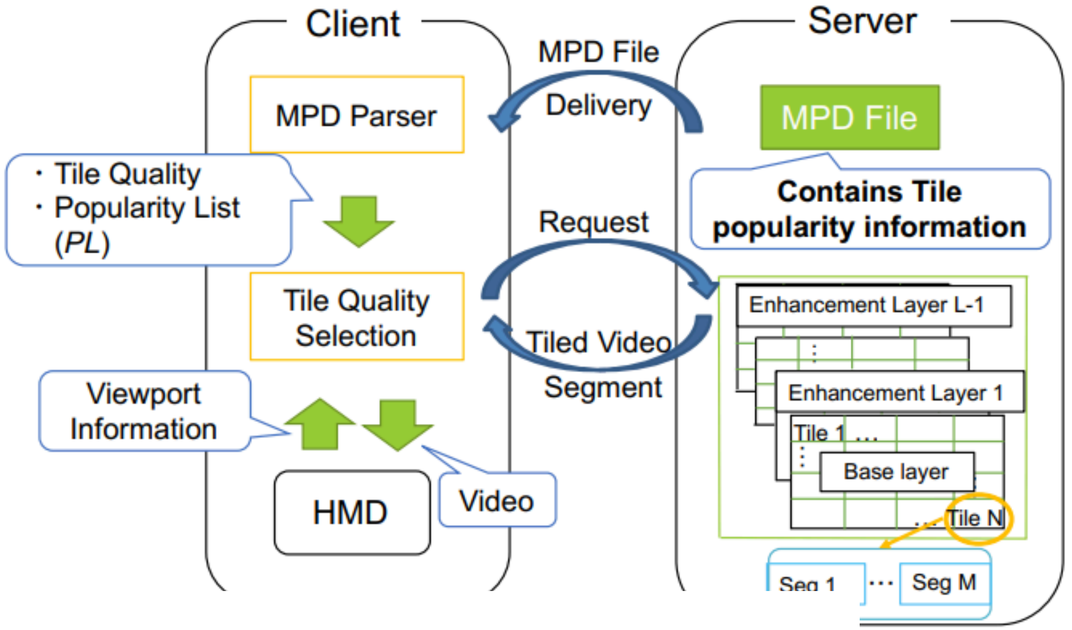

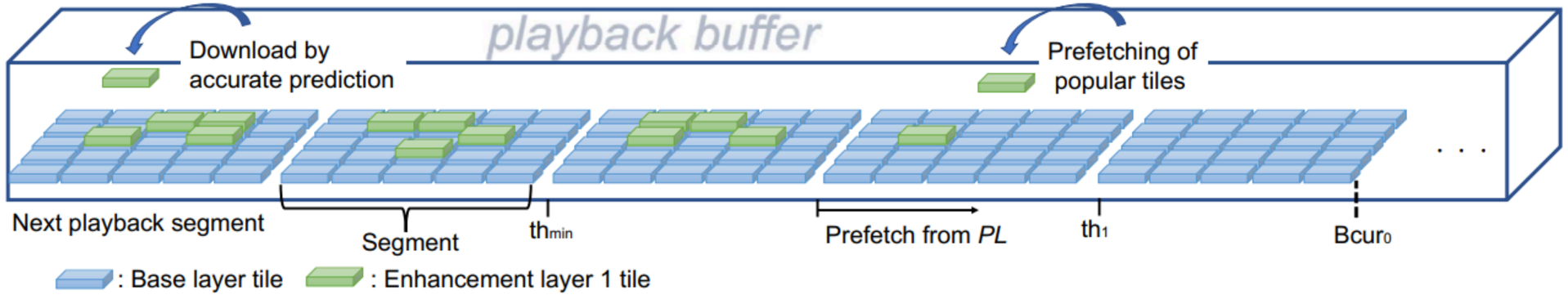

ICN & Metaverse

Further Reading

Statement: As TCP/IP is to the Web, ICN is to the...?

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Statement: RESTful Information-Centric Networking

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https://conferences2.sigcomm.org/acm-icn/2022/program.html