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GRADUATE SCHOOL AND RESEARCH CENTER
IN DIGITAL SCIENCE

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6GWS-250203

EURECOM View on 6G RAN

Agenda Item: 4

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6G RAN Design Principles

Concise and Efficient Specification

- Avoid redundant options with identical functionality
- Prioritize commercially valuable features

Unified Design

- Seamlessly integrate features (ISAC, Low-Power Signals, NTN, RedCap,…) from the start
- Harness synergies for enhanced efficiency and functionality

Compatibility with 5G

- Support same sub-carrier spacing, waveform and modulation
- Spectrum sharing and 5G channel coding as base-line

Energy-Efficient Communication

- Support of Energy Saving techniques from the start
- Mandatory support for basic low-power communication capabilities at UE

Selected Key Features

ISAC

- Including low-power communication

RAN Security

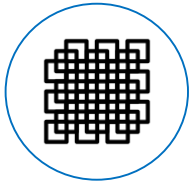
- Enhance security of low-level signaling especially during initial access

Integrated Low-Power Design

- PHY design compatible with Energy Detectors
- Enhancements for Small Data Transmission

Enhancements to Small Block Length Coding

- For instance DMRS-less control transmission



Extreme MIMO

- Serve large number of users (>128) on same resources
- Use device memory to super-charge MU-MIMO → Cache-Aided MU-MIMO

Cache-Aided Multi-User MIMO

Device Memory as New PHY Resource

Motivation

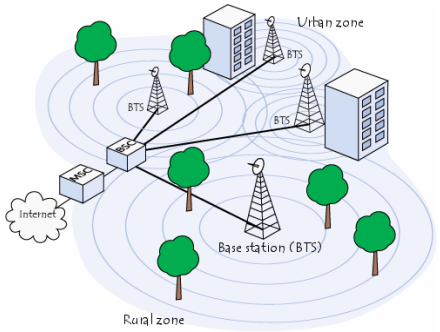
Video on-demand (VoD): ≥ 70% of mobile data traffic

- Very costly for providers to deliver VoD
- Most VoD is cachable and most users have a lot of memory in their pockets (cell phones)

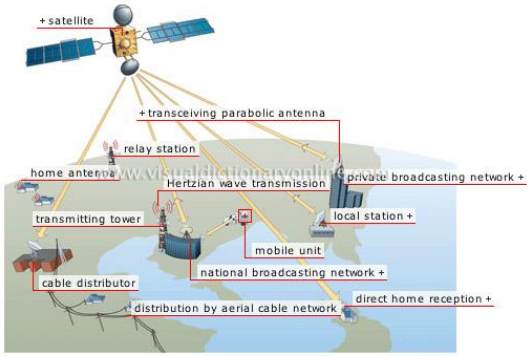
→ Use Device **Memory** as New PHY Resource !

Plenty of DL Use Cases for Cache-Aided Transmission

Wired or wireless communications

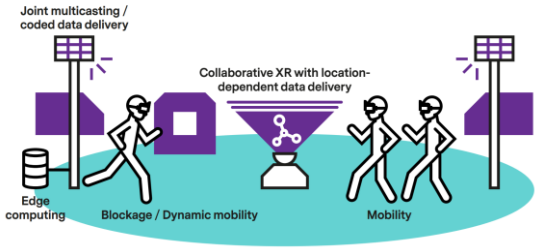


Satellite communications



In-flight communications

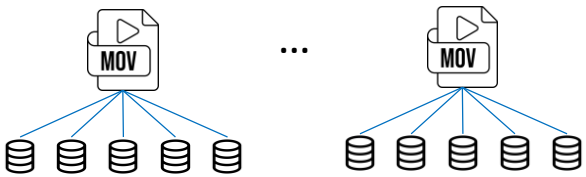
Virtual Reality



Technology

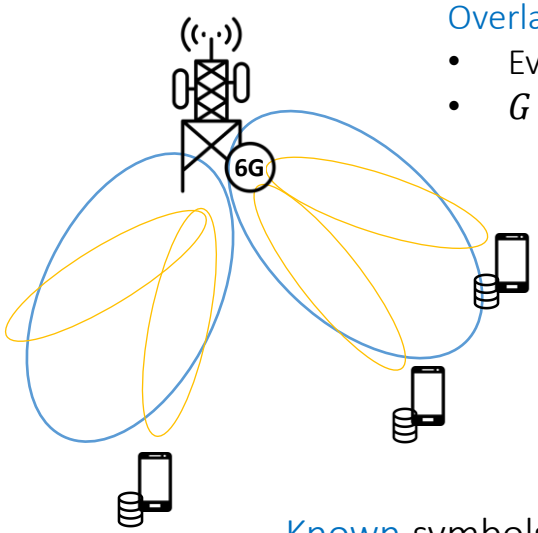
Library

Subpacketization



Cache placed in device memory

e.g. when network load is low



Overlaid MU-MIMO Transmissions

- Every UE can request any file in the library
- G MU-MIMO transmissions are super-imposed

$$\boldsymbol{x}_n = \boldsymbol{V}^{(1)}\boldsymbol{s}_n^{(1)} + \boldsymbol{V}^{(2)}\boldsymbol{s}_n^{(2)} + \cdots + \boldsymbol{V}^{(G)}\boldsymbol{s}_n^{(G)}$$

Single MU-MIMO transmission

Example: Received signal of UE 1 in Group 1

- Intra-group interference is subtracted

Known symbols from local cache

$$y^{(1,1)} = \underbrace{\bar{h}_{1,1}^{(1,1)} s^{(1,1)}}_{\substack{desired \\ signal}} + \underbrace{\bar{h}_{1,u_2}^{(1,1)} s^{(u_2,1)}}_{\substack{intra-group \\ interference}} + \underbrace{\bar{h}_{1,u_5}^{(u_5,3)} s^{(u_5,3)} + \bar{h}_{1,u_6}^{(1,3)} s^{(u_6,3)}}_{\substack{inter-group\ interference \\ from\ G_2}} + \underbrace{\bar{h}_{1,u_9}^{(u_9,5)} s^{(u_9,5)} + \bar{h}_{1,u_{10}}^{(u_{10},5)} s^{(u_{10},5)}}_{\substack{inter-group\ interference \\ from\ G_3}} + n$$

Mitigated via Precoding

Estimated via DMRS

Potential Gains are Significant

Library of 90% of Netflix Traffic

- About 100 most popular movies
- Assume each movie is 90min
- Buffering is 2min →1/45 of a movie

Full-HD Movies (2.47GB)

- Cache size = 25GB

→ Potential Gain Factor = 6 !

HD Movies (1.3GB)

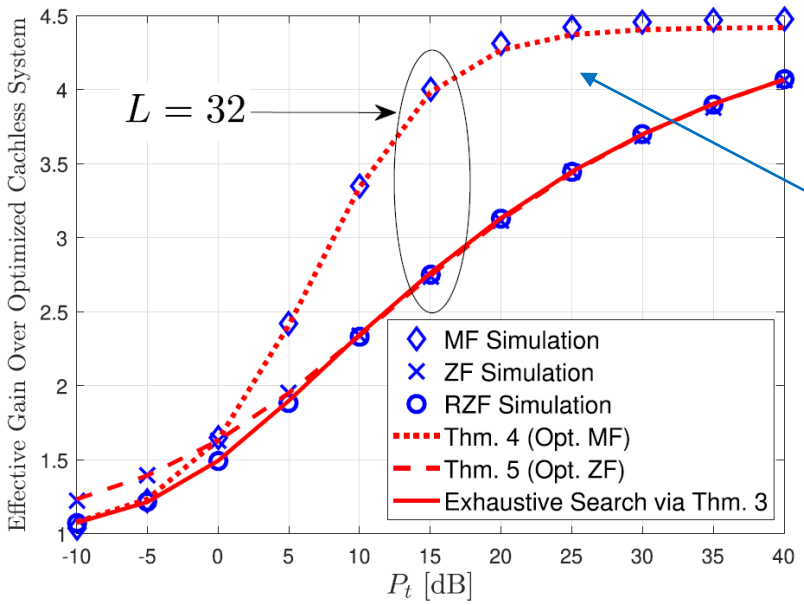
- Cache size = 25GB

→ Potential Gain Factor = 7 !

SD Movies (1.3GB)

- Cache size = 5GB

→ Potential Gain Factor = 5 !



With realistic CSIT costs → still gain of 3-4.5 over cache-less system

[1] H. Zhao, A. Bazco-Nogueras and P. Elia, "*Vector Coded Caching Multiplicatively Increases the Throughput of Realistic Downlink Systems*", IEEE Trans. Wireless Com., April 2023

Summary

- Multimedia Services (VoD, Virtual Reality,…) are consuming significant DL communication resources
- Devices have memory to intelligently cache this content
- The device cache can be used to super-charge the DL transmission
- The content can be delivered with large gains (300%-500%) in spectral efficiency
- Requires less RF-chains (and power/cost) than comparable conventional MU-MIMO transmission