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Standardization aspects of Caching and Coded Delivery in MEC integrated 5G system

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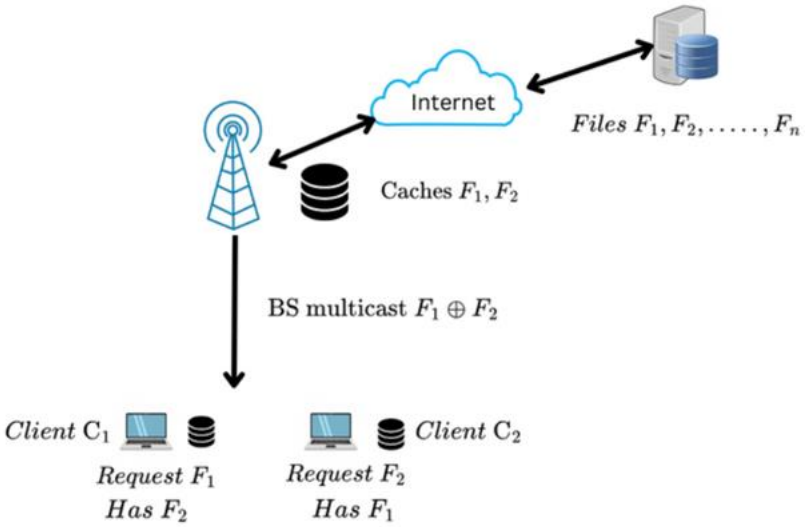
Content Caching

- Content caching at the network edge has long been recognized for enhancing content delivery to users since the Internet's early days.
- Extensive research has been conducted highlighting the benefits of caching content within cellular networks [3-5].
  - These studies cover content caching across various base stations, including macro-cell, micro-cell, and femto-cell BSs.
  - Several studies suggest caching in MEC storage to enhance content delivery.

Coded Delivery

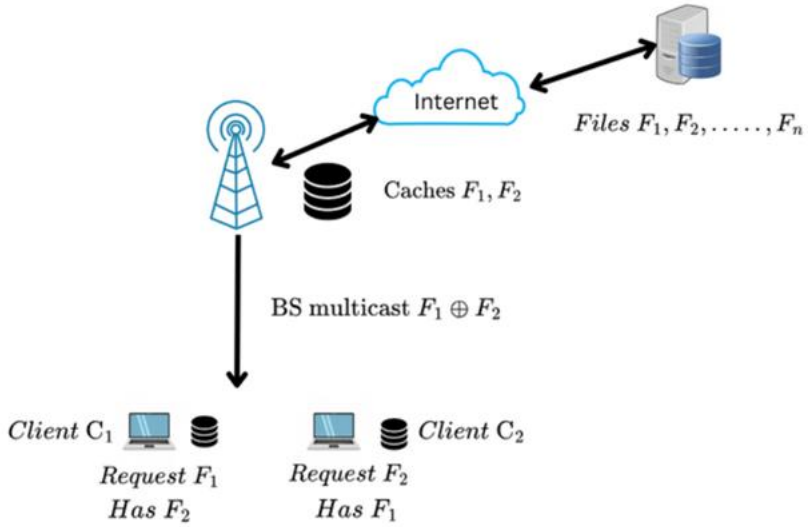
- **Coded Delivery**
  - Involves the server broadcasting or multicasting a coded information stream to multiple clients (e.g., utilizing index codes)
  - Broadcasted data stream is received in parallel by the intended clients, who subsequently decode the information intended for them.
    - For coding and decoding, simple XOR operation is used
  - Studies show that coded delivery improves content delivery, notably by reducing bandwidth needs [11], [12].

Coded Delivery example



- Consider two clients (C_1 and C_2), a storage close to the base station (BS) cache files F_1 and F_2 within the network.
- If C_1 previously requested file F_2 and C_2 requested file F_1. Both C_1 and C_2 now possess the respective files in their caches.
- In the event C_1 reiterates its request for F_2 (or C_2 for F_1), the content can be directly served from their caches.
- Similarly, content cached within the cache close to the BS is employed to fulfill content requests from clients associated with the BS.

Coded Delivery example (cont..)



- When C_1 requests F_1 and C_2 requests F_2, their requests are relayed to the BS.
  - The BS subsequently multicasts $F_1 \oplus F_2$.
    - C_1 and C_2 can independently recover F_1 and F_2 by applying XOR operations to the coded multicast.
    - C_1 computes $F_2 \oplus (F_1 \oplus F_2)$ to recover F_1, while C_2 computes $F_1 \oplus (F_1 \oplus F_2)$ to recover F_2.
- Content cached near the BS facilitates coded delivery. If the cache lacks the content, it's fetched from the remote server.
- Caches near the BS or client can be filled proactively using predicted or dynamic caching policies.

Proposed work

- **This paper investigates:**
  - the standardization aspects of a **caching and coded delivery system** in a MEC [17] integrated 5G system that leverages 5G Multicast Broadcast Services (MBS) [18], [19].

- **The system considers:**
  - (i) caching of content at the end-user devices as well as MEC storage
  - (ii) transmission of coded multicast of end-users' content requests from MEC
- Content requests of the end-users are recovered from the coded multicast using the side information, i.e., the content cached at the end-users' caches
- Contents cached are previously requested and stored contents

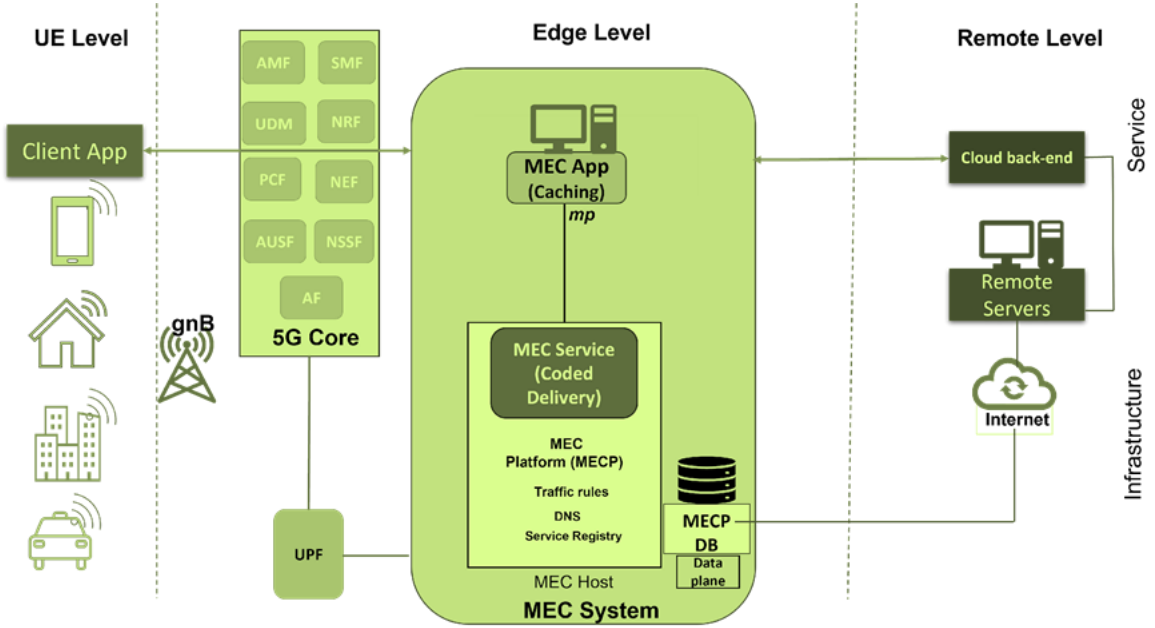
Standardization at the edge

- Edge computing can play a pivotal role in enabling technologies that are latency-critical and sensitive to quality, for example, video streaming applications.
- Standard development organizations (SDOs) play a critical role in enabling edge computing when numerous stakeholders are involved in the solution.
  - Common infrastructure capabilities, intelligent application placement, service continuity, discovery, optimum (re)routing, and federation across Multiple Network Operators (MNOs) are among the requirements that must be adhered to.
- The ETSI MEC system offers application deployment along with additional services that can be used by applications and MEC platform.

Coded Delivery as a MEC Service

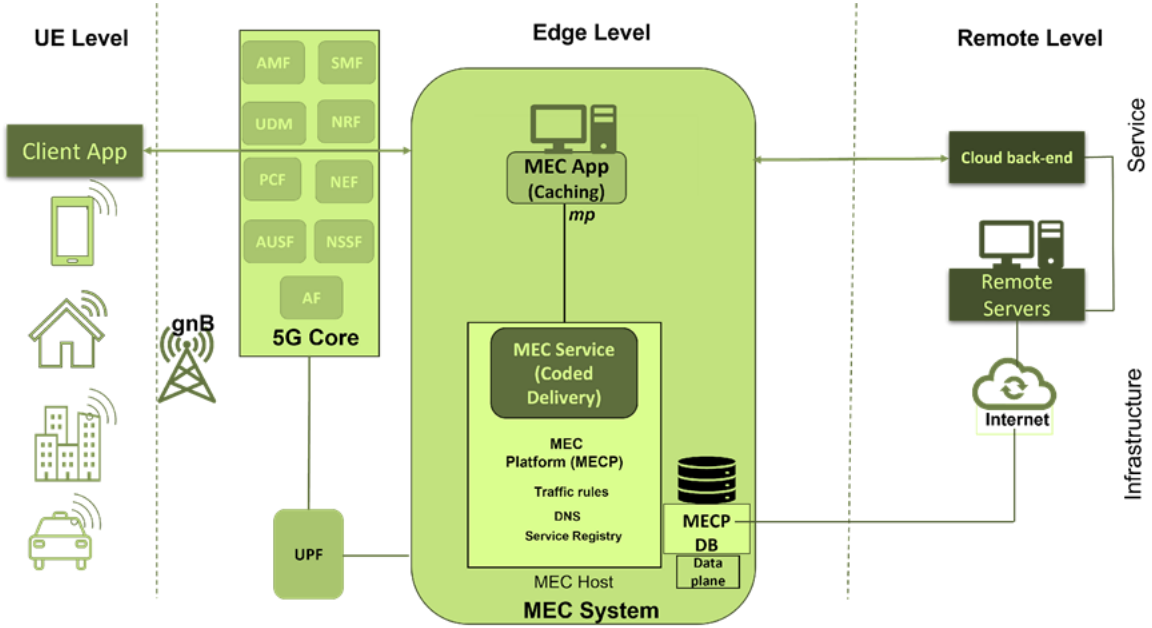
- In this work, we propose
  - a standardized deployment of coded delivery as an MEC service within the broader framework of MEC.
  - The coded delivery MEC service is seamlessly integrated with the Multicast Broadcast Service (MBS) through AF to efficiently deliver coded multicast content to end-users.

Coded Delivery as a MEC Service (cont..)



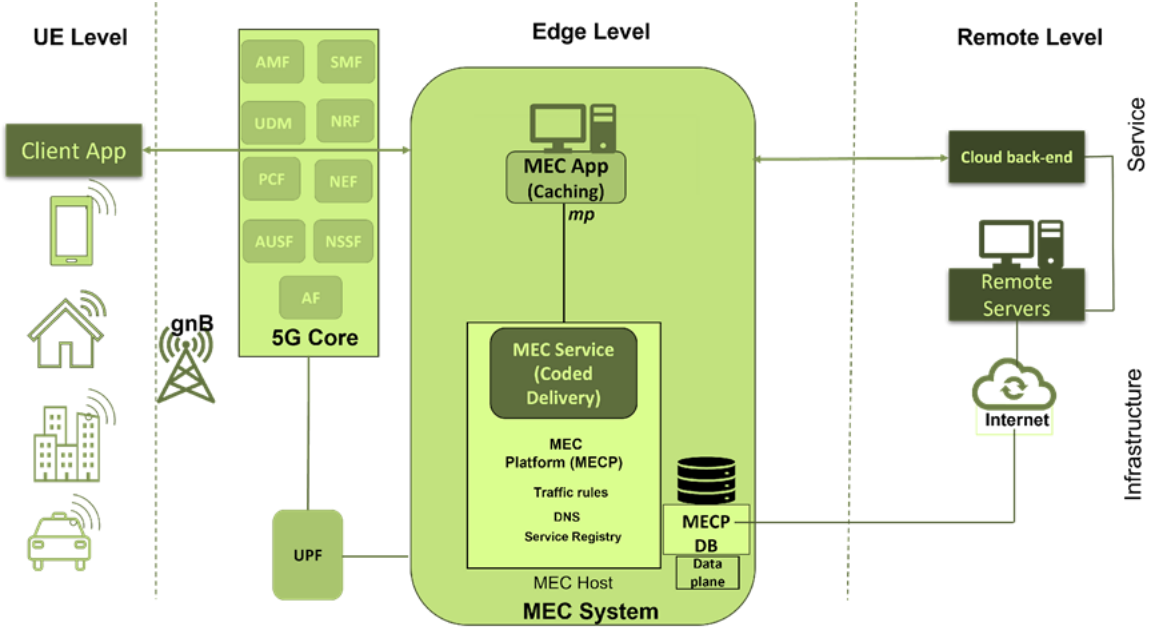
- The ETSI ISG MEC architecture [17] outlines the entities, interfaces, and messages for UEs to deploy applications on a MEC host (MECH) and access MEC services.
- The MEC app is instantiated at the MEC host.
- The client app on the UE identifies supported MEC apps via the device app, selects one, and requests its onboarding and instantiation.
- Coded delivery operates as a MEC service, and available applications like caching can be utilized on the MEC platform.

Information Flow



- A caching application can serve the UE from its cache or retrieve from a remote server. If content isn't in the cache, it's fetched and cached at MEC. Once cached, the MEC app coordinates with MEC coded delivery.
- When the UE's content request reaches the MEC platform, it's directed to the caching application (MEC app), which then utilizes the coded delivery service.
- The MEC platform shall support this scenario by classifying the traffic and performing the appropriate routing.

Information Flow (cont..)



- A MECH is set up to run the caching application at the Edge Level, using its pre-configured URI.
- The UE provides the MEC's coded delivery service URI to the caching application server, which then configures and initiates the MEC coded delivery service.
- The video streaming app on the UE registers for coded delivery within the MEC service.
- The MEC app runs logic to aid coded delivery to the UE, updating the MEC service based on data from the cloud server and continuously feeding the UE.

Coded Multicasting

- Transmission of coded multicast:
  - MEC service utilizes the Multicast Broadcast Service (MBS) of the 5G system.
  - The MEC service accesses the Network Exposure Function (NEF) through the Application Function (AF) to access the MBS service.
  - An MBS session is established and configured via NEF or Multicast Broadcast Service Function (MBSF).
    - The information related to the MBS service is then communicated to the User Equipments (UEs) to which the coded multicast is to be sent.
- Coded multicast opportunities:
  - To determine coding opportunities in real-time with minimal delay
  - learning algorithms may be employed to predict content requests and identify potential coding opportunities.

Conclusion

- The paper:
  - Explored synergy between content caching and coded delivery in 5G MEC.
  - Investigated standardization within 5G, utilizing MEC and Multicast Broadcast Services (MBS).
  - Introduced a seamless MEC service for coded delivery integrated with MBS.
  - Established a standardized framework for coded delivery and caching in dynamic 5G MEC, enhancing application performance like video streaming and AR/VR for future 5G advancements.

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Thank You