Cloud Assisted Traffic Redundancy Elimination for Power Efficiency in Smartphones

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Outline

- Background and contributions
- System design
- Performance evaluation
- Conclusions

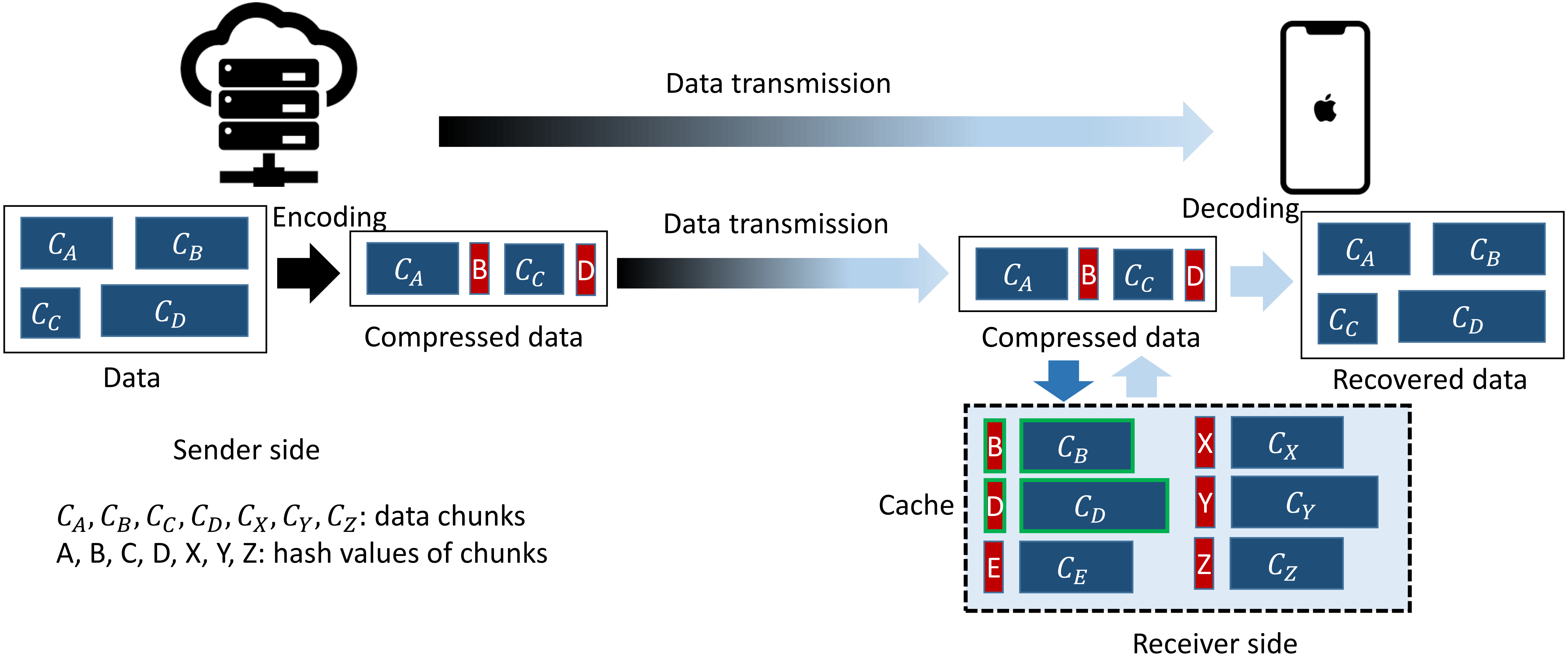
Background: Exceptional increase in smartphone usage

A massive increase in data traffic from application servers to smartphones

- **Strains the computation capacity** of smartphones
- **Strains the batteries** of smartphones
- **Bog down the last hop** in data transmission

Traffic redundancy elimination (TRE)

Background: Traffic redundancy elimination (TRE)



$C_A, C_B, C_C, C_D, C_X, C_Y, C_Z$: data chunks
A, B, C, D, X, Y, Z: hash values of chunks

Background: Existing TRE methods

Existing TRE methods:

- **Receiver-based TRE**
  + Receiver has cache
  - Large amount of up-link synchronization overhead
  - Low cache hit rate

  i.e. Asymmetric caching (AC), MobiCom 2012

- **In-network TRE**
  + caching is deployed in network (routers, switches)
  - No TRE at the last hop

  i.e. WAN optimization, Riverbed Networks

- **Sender-based TRE**
  - Both sender and receiver have caches
  - Inefficient cache usage
  - huge workload at the server side

  i.e. EndRE, NSDI 2010

Shortcomings:

- **Existing methods conduct TRE against any application**, however, due to the limitation of memory resource at smartphones, such TRE will result in the **low cache hit ratio, and also less power conservation at smartphone**.

Contributions

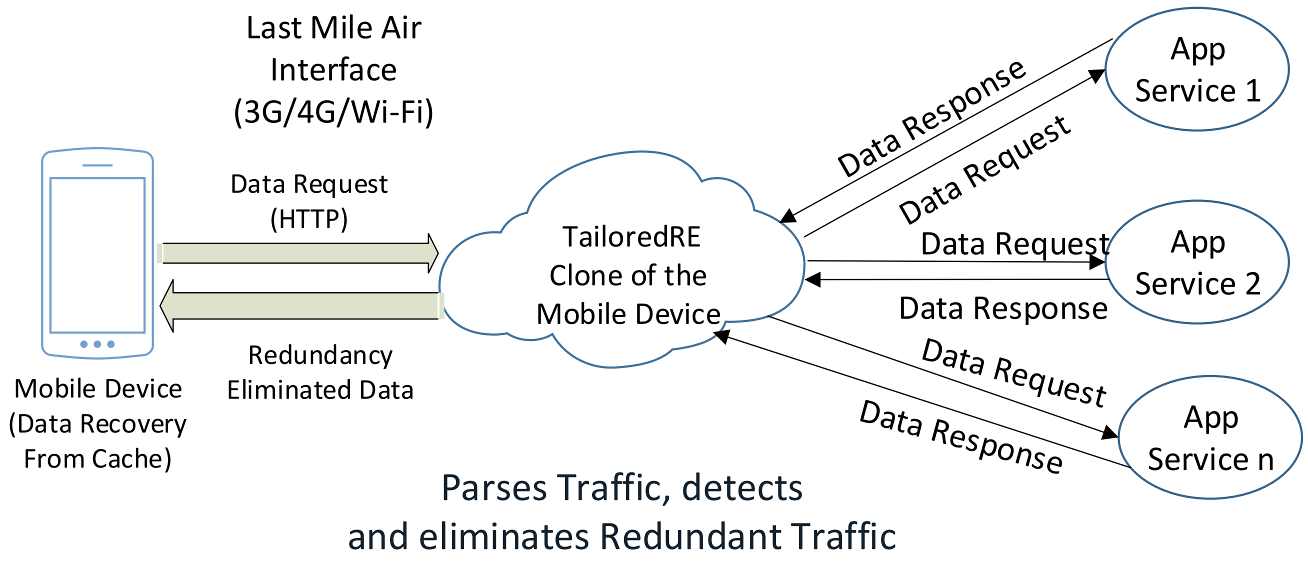
To solve these challenges, we propose a novel TRE system, called ***TailoredRE***, that incorporates three components:

- To reduce the computing and up-link bandwidth overhead on smartphones, the proposed TRE is **cloud clone assisted**.
- To enhance the cache hit rate, so that more power consumption needed for data transmission can be reduced, the proposed method conduct TRE by **tailoring to individual user's activities**.
- To conserve the cache cost at the cloud, **the clones in the cloud are grouped and their caches are shared**.

System design

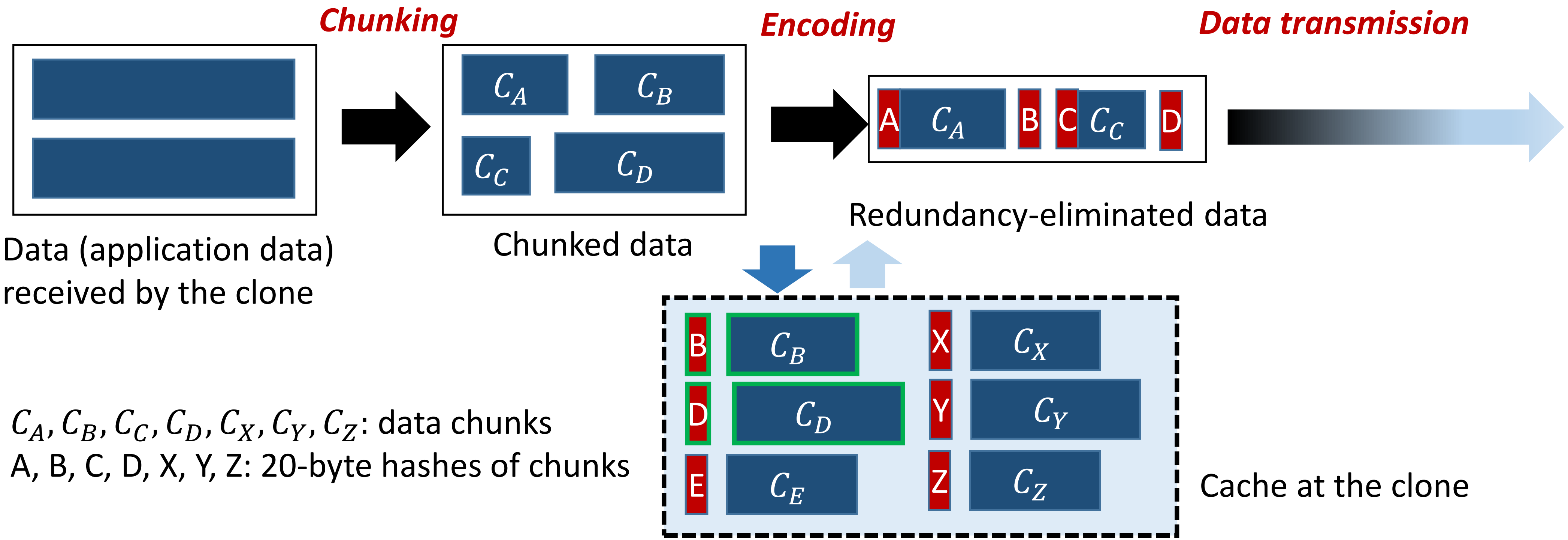
- Cloud clone assisted TRE
- Personalized and application TRE
- Cache sharing among clones

Could clone assisted TRE: overview



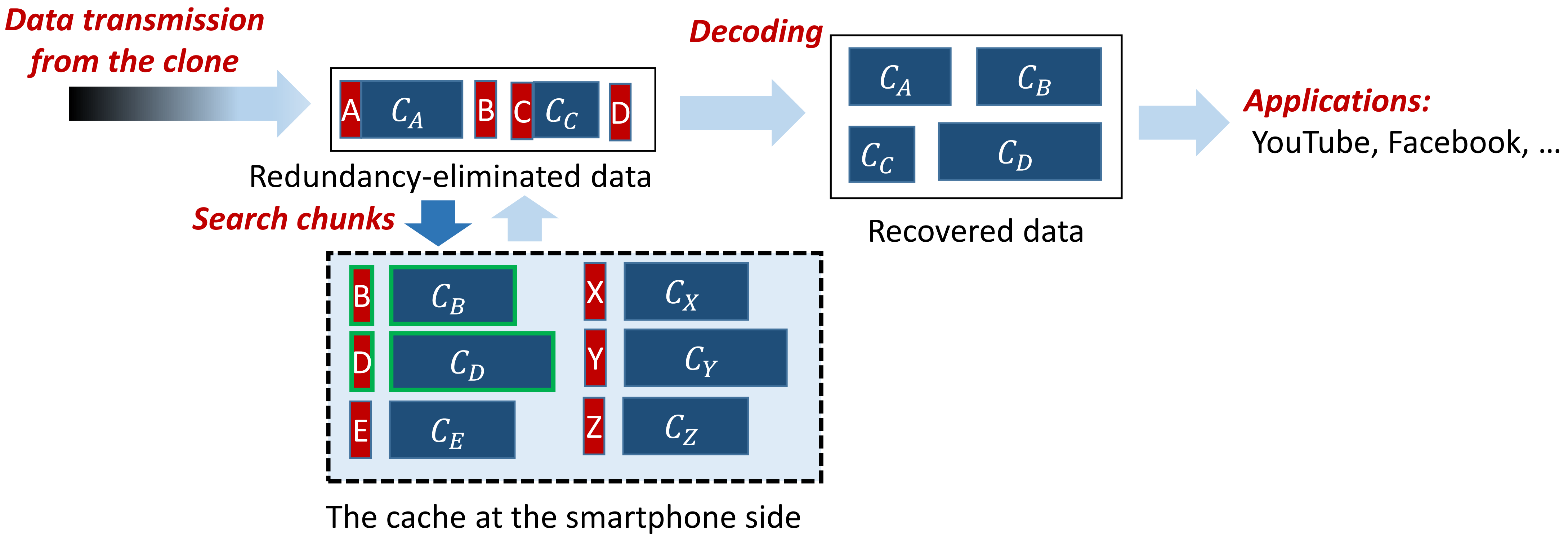
- ***Clone:*** **Each smartphone has a clone in the cloud**, which is a program running in a virtual machine (VM) to conduct TRE for its belonged smartphone.
- ***Data flow path:*** **server <-> clone (in cloud) <-> network <-> smartphone TRE client**

Cloud clone assisted TRE: Clone side



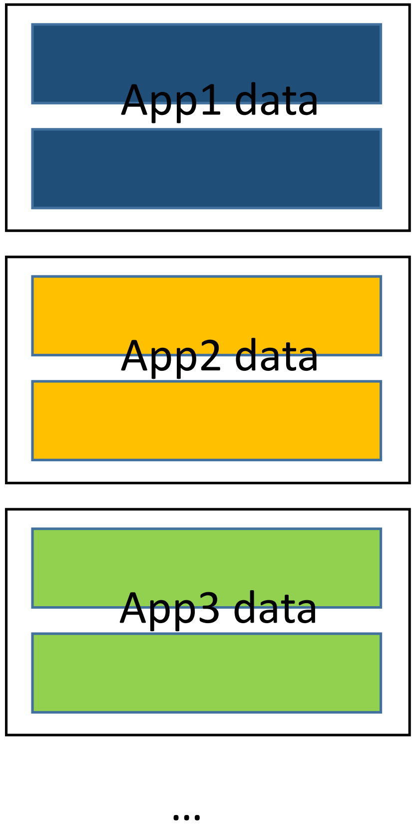
- ***Chunking algorithm:*** find the local maximum byte value in the to-be-sent data as **chunk boundary**.
- ***Encoding:*** use SHA1 to **compute the hash** for each chunk; if a chunk is found in the cache, then **encode chunk with its corresponding hash** in the data, otherwise, put the chunk and its hash value in the cache.

Could clone assisted TRE: Smartphone side



- ***Search chunks***: if chunk is found in the cache, get the chunk; otherwise, insert the chunk and its hash in the cache.
- ***Decoding:*** replace the hashes with the found chunks.

Personalized and application-adaptive TRE



- ***Personalized TRE:*** The clone performs TRE only on applications that have historically presented **higher cache hit rate** and larger **accumulative transmission volume, which are related to user's smartphone usage behaviors.**

The clone performs TRE against only App1, while neglecting App 2 and App 3.

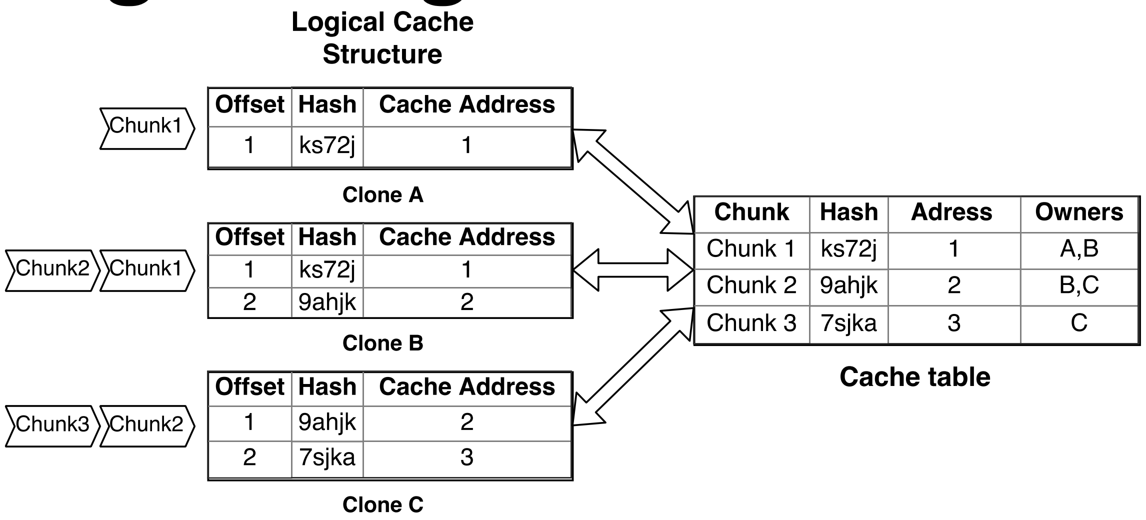
Chunking → ***Encoding*** → ***Data transmission***

Application	cache hit ratio r	Relative volume a	benefit factor
App 1	***0.9***	***0.4***	***0.36***
App X	***0.3***	***0.2***	***0.06***
App Y	***0.5***	***0.25***	***0.125***
…			…
APP 2	0.2	0.001	0.002
APP 3	0.3	0.001	0.003

Benefit factor = $\boldsymbol{r} \cdot \boldsymbol{a}$

r_i: the average cache hit ratio of application i for the user;
a_i: relative data volume of application i for the user;
r_i, a_i are the statistic information of application i computed for each clone in the cloud;

Cache sharing among clones



- ***grouping:*** **The clones on the same VM in the cloud are grouped according to the similarity of user's application interests by use of locality sensitive hash (LSH).**
- ***Cache sharing:*** **The grouped clones share the caches with 2-layer cache sharing strategy.**

- Logical cache: each clone has its own logical cache, which is logically independent with other clones. It is **used for the synchronization** between the individual clone cache and the cache at its corresponding smartphone.

- Physical cache: the grouped clones share a common physical cache, **where the chunks are virtually stored**. Only one copy of a chunk is stored in the physical cache, and only if all a chunk is removed from all the logical caches, the chunk will be removed from the physical cache.

Performance evaluation

- Data trace collection and analysis
- Trace-driven simulation
- Prototype-based simulation

Data trace collection and analysis

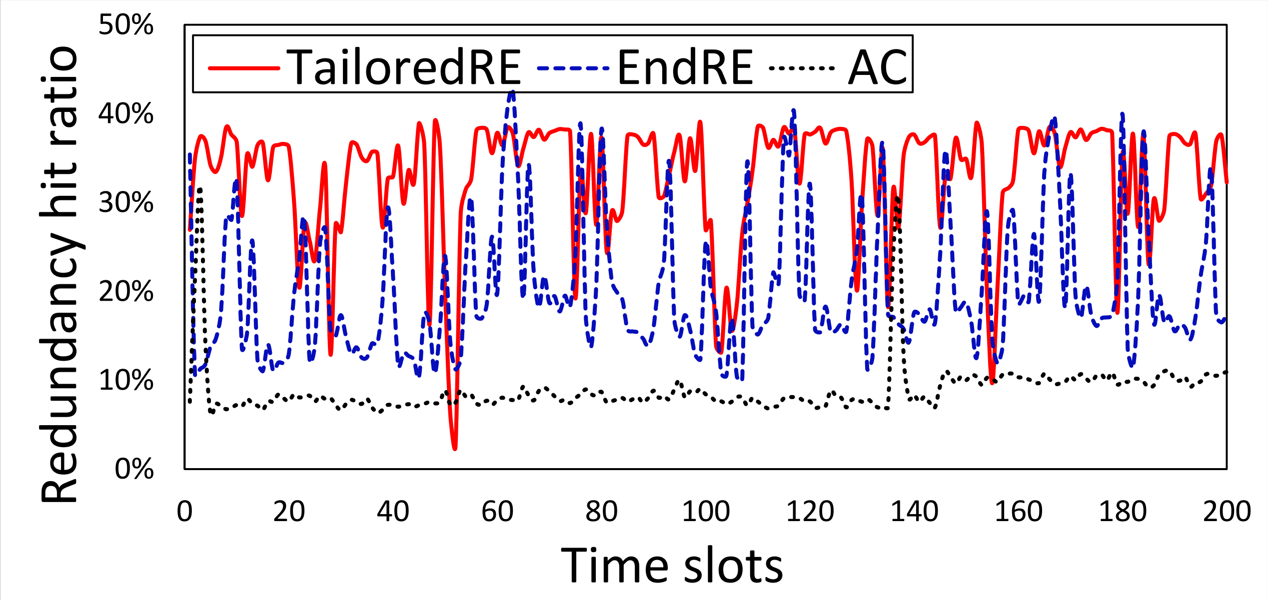
TRACE POOL

Number	Traces	Size (GB)	Redundancy hit ratio
1	WebBrowser1	0.85	90.18%
2	Techcrunch1	1.11	76.10%
3	Techcrunch2	1.09	74.09%
4	Bloomberg1	1.28	69.47%
5	NYTimes1	1.40	52.60%
6	Bloomberg2	0.90	40.67%
7	Quora1	1.36	26.73%
8	Quora2	0.81	22.26%
9	Quora3	1.12	20.41%
10	Twitter1	1.03	20.10%
11	CNN1	0.98	20.01%
12	Instagram1	1.40	19.57%
13	Spotify1	1.01	18.17%
14	Twitter2	1.13	17.91%
15	Instagram2	0.84	17.68%
16	YouTube1	1.58	17.58%
17	YouTube2	1.02	16.31%
18	Facebook1	0.94	9.80%

Wireshark based traffic sniffing on windows 10

- ***Traces Collection:*** **use Wireshark to sniff traffic from servers to the smartphone.**
- ***Redundancy analysis:*** **The redundancy ratio was analyzed.**

Trace-driven simulation: cache hit rate



Cache hit ratio: $\frac{V_{hit}}{V_{total}}$

V_{total}: the total number of bytes of chunks received by the client;

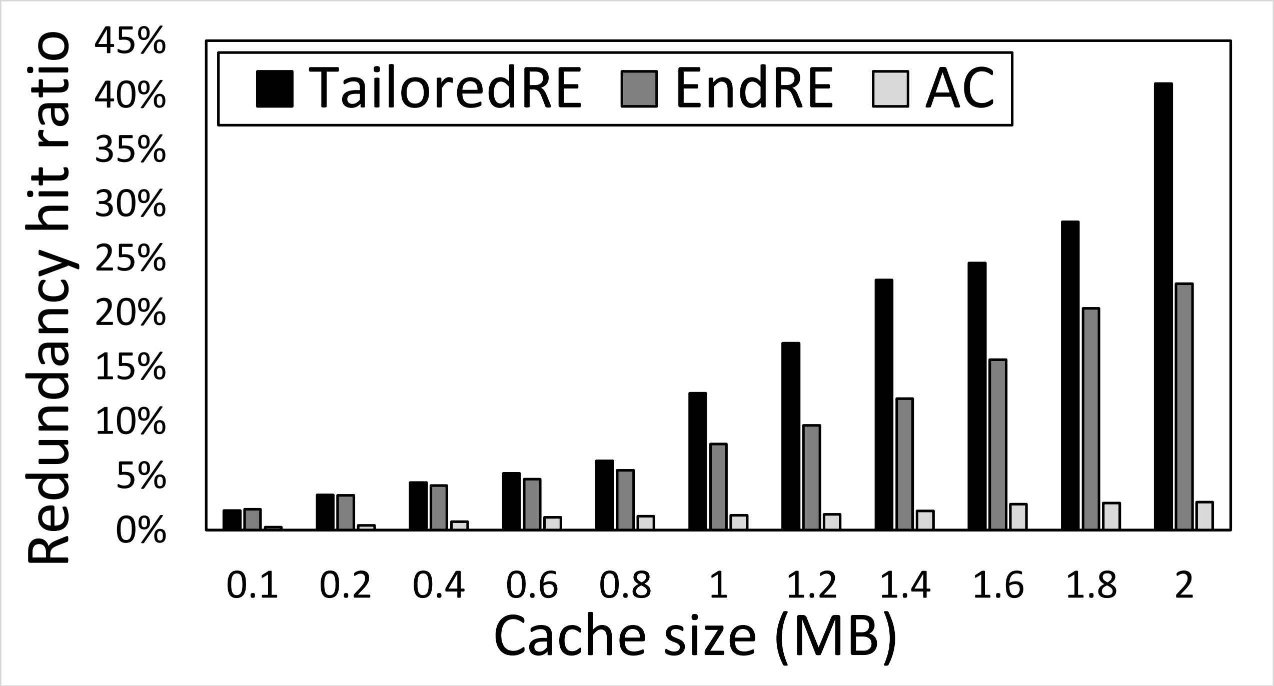
V_{hit}: the total number of bytes of chunks that hit the cache at the client.

Compare methods:

- **EndRE:** a sender-based TRE method that conducts TRE against any application;
- **AC:** a receiver-based TRE method where the caches at the sender and receiver are asymmetric.

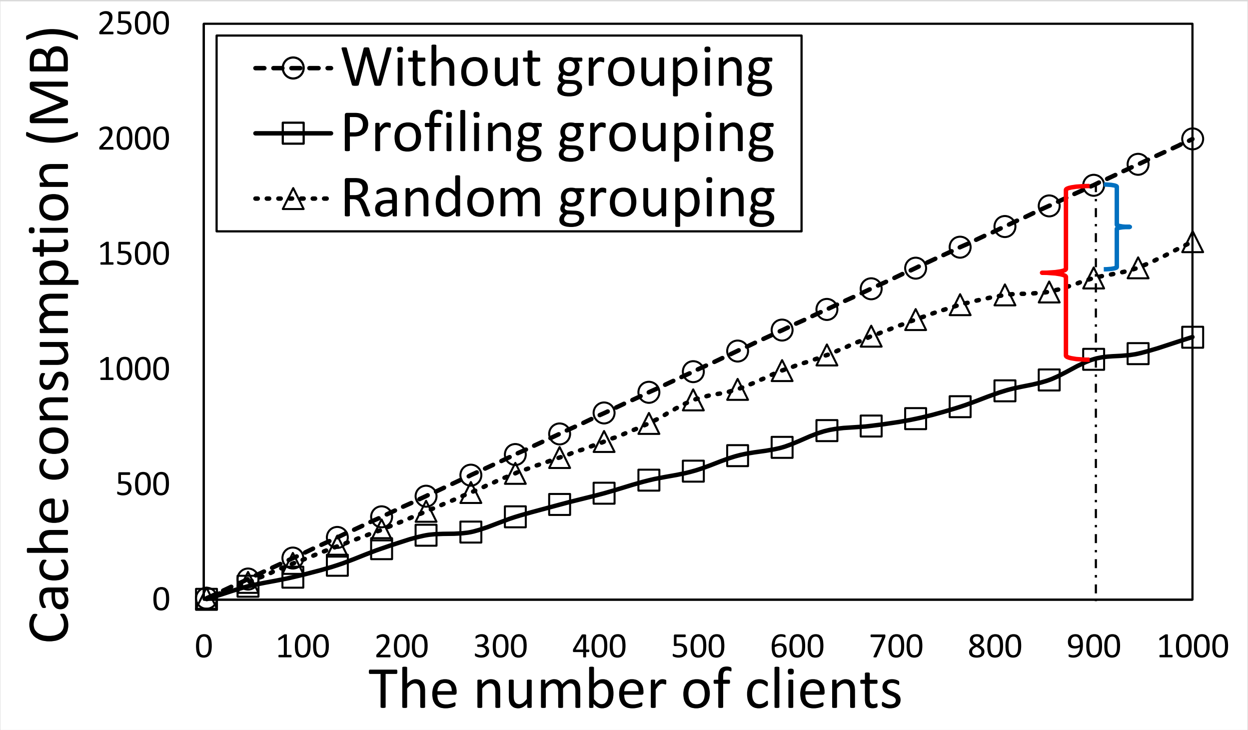
- ***Cache hit rate:*** **The proposed method has superior cache hit ratio compared with EndRE and AC, because it always select the applications that have higher rate and most frequently used by users.**
- ***Stability:*** **The proposed method has more stable hit ratio over time.**

Trace-driven simulation: cache hit rate



- ***Cache hit rate:*** **The cache hit ratio increases with the increase of the cache size at the receiver side.**

Trace-driven simulation: efficiency of cache sharing



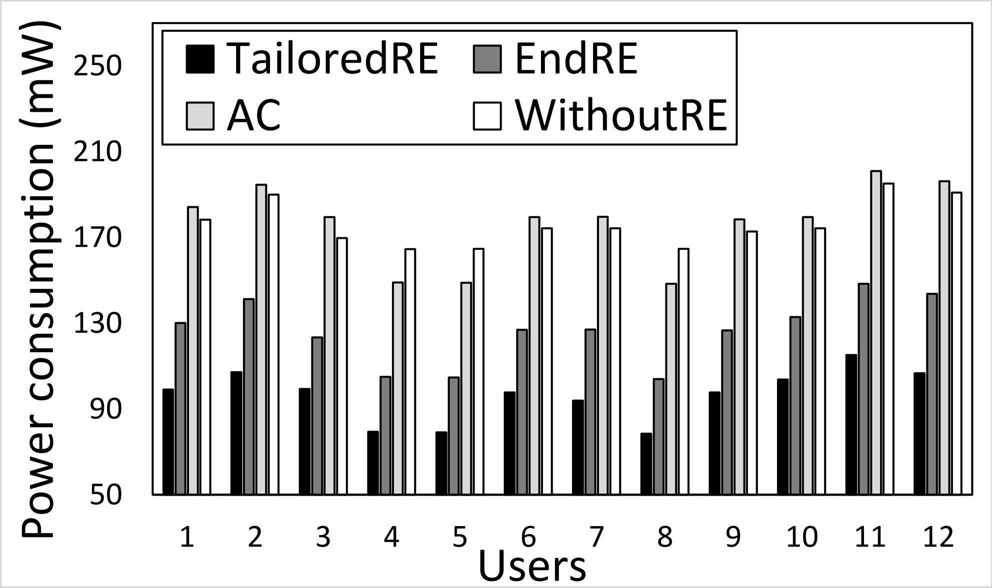
Cache size: 2MB
Number of clones (clients): 1- 1000
Similarity: 0.4
Max cluster size:

- *Cache saving:* **Profiling grouping (the proposed cache sharing method) conserve half of the cache resource, which is superior efficient compared with random grouping.**

Prototype based simulation: power efficiency

User application preference

Applications	Time in one week (h)
YouTube	0.5-2
Facebook	0
CNN	2.0-4.0
Quora	0.5-2.0
Techcrunch	2.0-4.0
NYTimes	0.5-2.0
Twitter	2.0-4.0
Instagram	2.0-4.0
Spotify	2.0-4.0
Bloomberg	0.5-2.0
Browser	0.5



A survey about user application preference for 12 users
Python-based clone prototype
Android-based smartphone TRE client

- ***Power consumption:*** **the proposed method result in the lowest power consumption across the 12 users, because it has the highest cache hit ratio and needs the least data transmission.**

Conclusions

A novel TRE system, TailoredRE, is proposed for power efficiency in smartphones, which has the following properties:

- ***Cloud clone assisted TRE:*** **the TRE computing is performed in the cloud;**
- ***Personalized and application adaptive TRE:*** **TRE is performed against selected applications that a user more frequently access and have high redundancy hit ratios for each individual user;**
- ***Cache sharing among clones*****: TailoredRE groups the clones in one VM based on user interests, and let the clustered clones share contents with each other.**

Thank you!
Questions & Comments?

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