Faster Data Rates via Caching on Smart Devices

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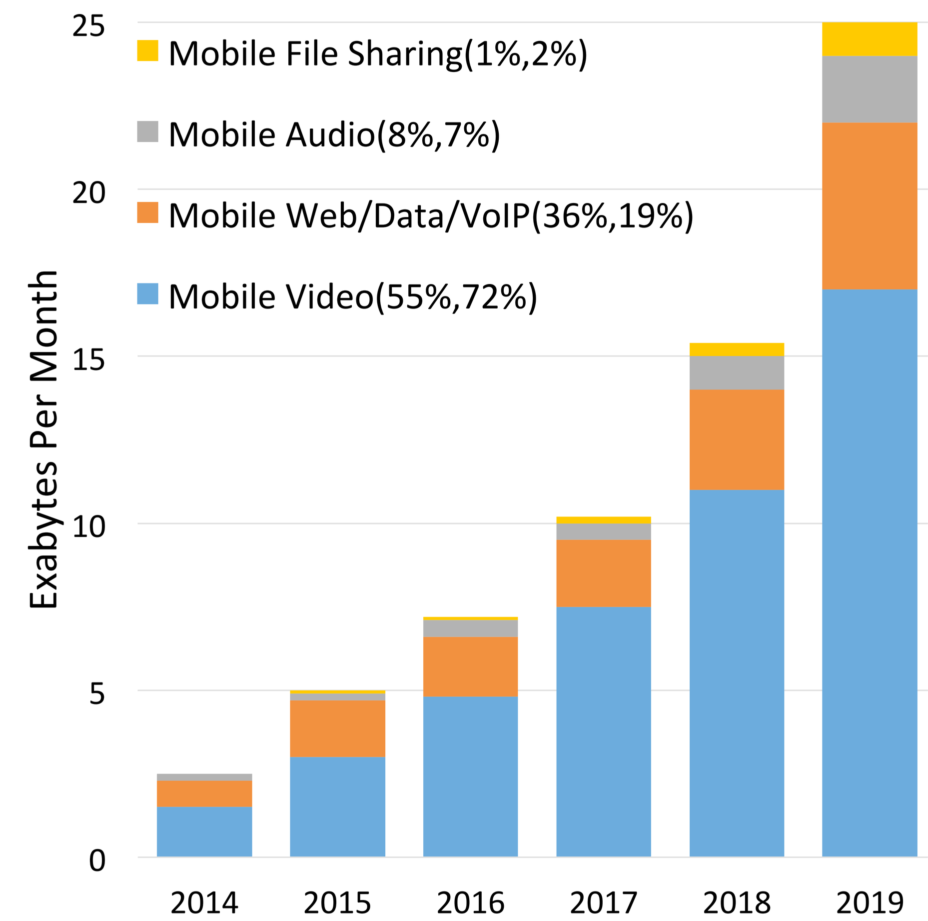
The Problem

Wireless networks have been struggling the most to cope with the exponentially increasing demand for higher data throughput.

Overall mobile data traffic is expected to grow to 24.3 exabytes per month by 2019, nearly a tenfold increase over 2014 [1].

By 2019, mobile video accounts for 72% of this traffic.

Given that we are already reaching Shannon's theoretical limits on the capacity of the wireless channel, we aim to investigate novel methods for temporal spectrum re-use through data caching to meet the soaring wireless data traffic.



Index Coding Example

The base station can satisfy the 4 requests by broadcasting only 2 coded packets (index code).

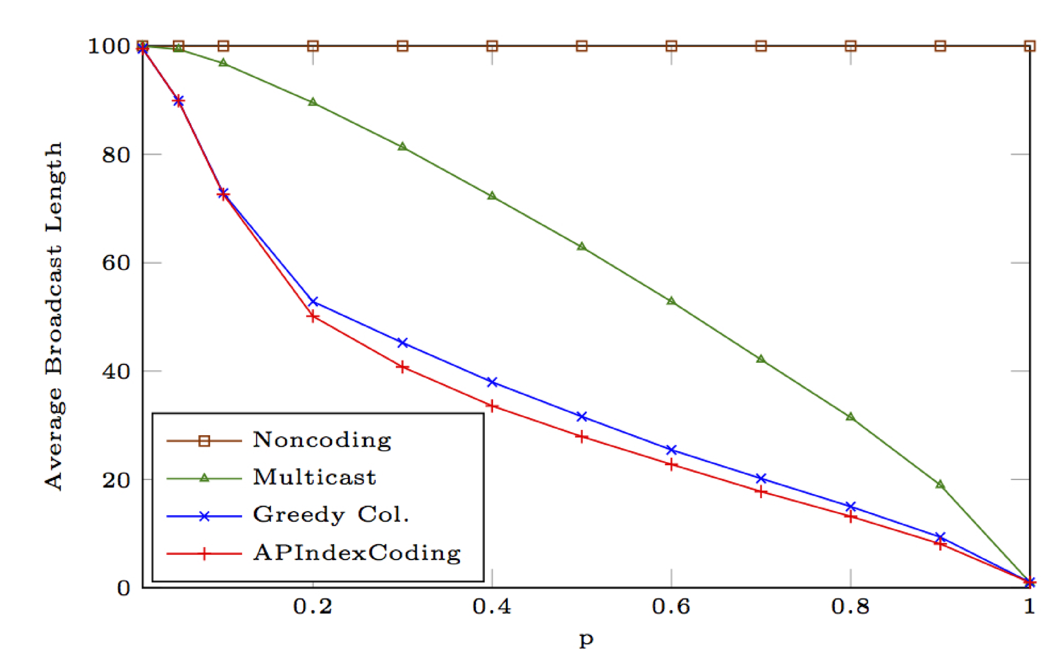
Each phone can decode his message by using the broadcast message and his cached data.

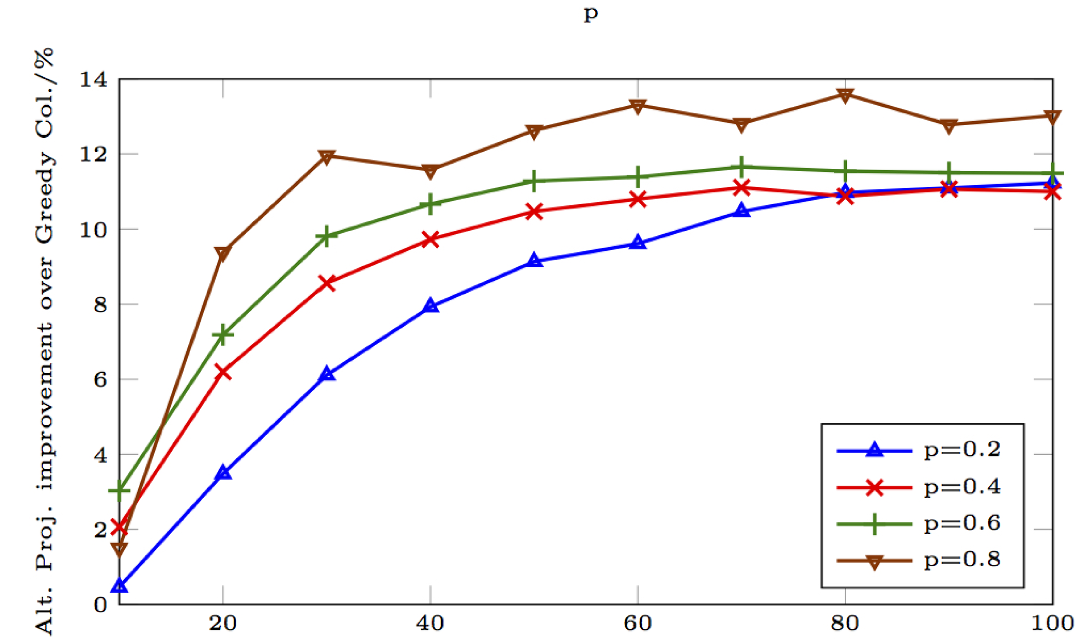
Optimal index code?

Finding the optimal index code is equivalent to completing the "caching" matrix below such that its rank is minimized [2]. This is know to be NP-hard.

	X_1	X_2	X_3	X_4
t_1	1	$*$	$*$	0
t_2	$*$	1	$*$	0
t_3	0	$*$	1	$*$
t_4	$*$	0	0	1

Simulation Results





The top figure shows the average broadcast length obtained by various algorithms (Noncoding, Multicast, Greedy Coloring on complement graphs and APIndexCoding on undirected subgraphs) for random cache with the number of user $n = 100$.

The bottom figure shows that our proposed heuristic lead to a 10% extra savings on broadcast packets compared to the greedy graph coloring solution studied in the literature.

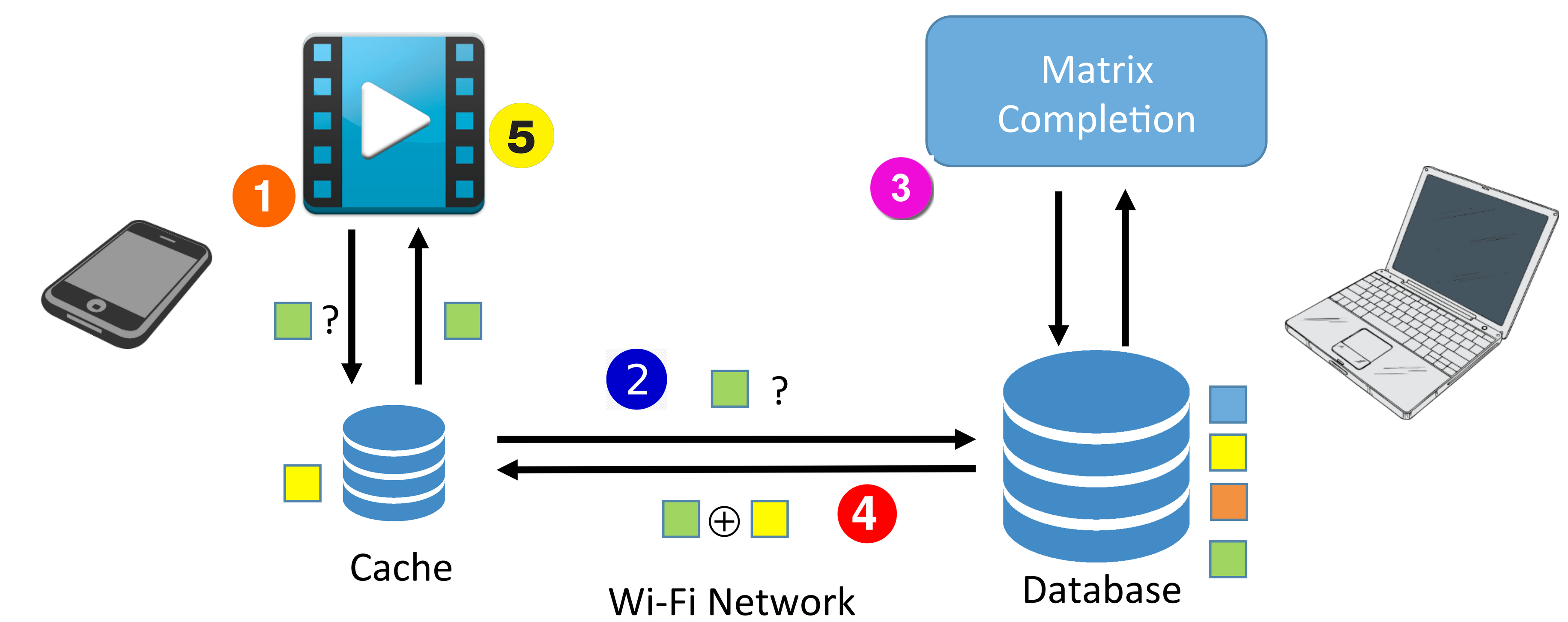
Challenges

One of the major challenges in SmartCache is that users can enter or leave the network whenever they want to. The server has to adjust the encoding at real time.

Scalability is also one of the challenges which has to be addressed in SmartCache. Since the server is centralized, as the number of users increase, the load on the server also increases as it is responsible for matrix completion.

The biggest challenge in SmartCache is to guarantee users' data privacy. The user should not be to access unauthorized contents using his cache contents.

Framework



We implemented the client as an Android phone application, and the server as a JAVA application. The communication between the client and the server uses the UDP multicast protocol over wireless networks. The XOR operations are applied frame by frame between the two video files. The video source uses the MJPEG codec, which supports the intra-frame compression. The Matrix Completion Module uses a LDG clique-cover algorithm. The cache contents are stored as RAW resources in the Android application.

Main Steps:

1. Users (client side) request to watch certain videos on their smart devices.

2. Upon a cache miss, a client sends request to the server with its cache information.

3. The server collects all the client requests within a time window to generate a matrix, and use the Least Difference Greedy (LDG) clique-cover algorithm to compute the best transmission strategy.

4. The server multicasts the corresponding XOR-ed messages back to the clients to minimize the bandwidth consumption.

5. The clients decode the message with the information stored in their caches, and users can watch the video on their smart devices.

References

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