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Capacity Scaling in Wireless Device-to-Device Caching Networks

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Introduction

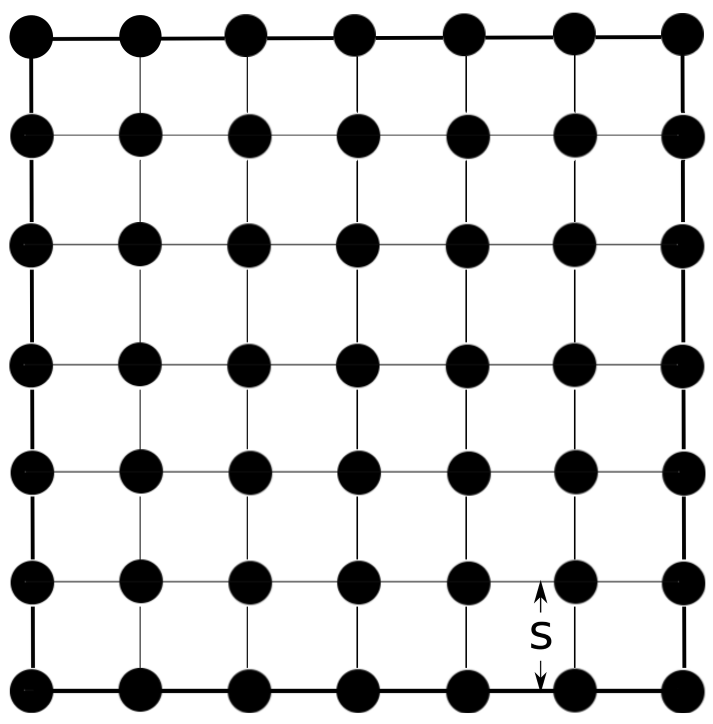
- The bottleneck of current wireless cellular network is the spectral efficiency of the Base Station, which does not scale with the number of users.
- We want to solve this problem by using distributed caching and Device-to-Device (D2D) communication.

Motivation

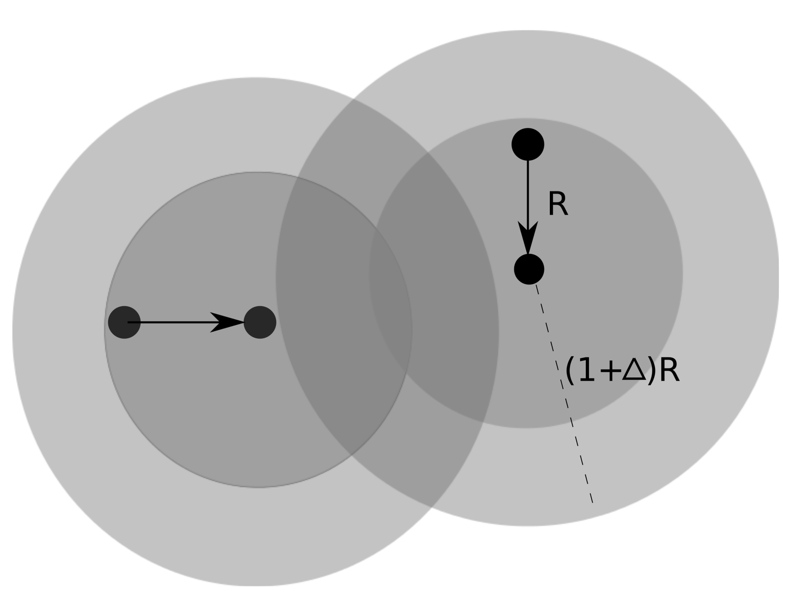
- There are some redundancies of the requests from users.
- Modern smart phones and tablets have large storage capacity.
- Wireless D2D communication happens in short distance and can achieves very high spectral efficiency.

Network Model

- We consider a squared dense network of area 1, where n nodes are distributed on a grid.
- We consider the delivery of messages from a library of m (function of n) possible messages (files) to the nodes.
- Users make statistically independent requests for a message in the library according to a Zipf distribution with parameter 0< γ_r < 1.
- Nodes cache the messages at random, and it is assumed that each node can cache at most one message.
- Protocol Transmission model is used and only-one hop transmission is allowed.
- If the users that cannot find the message in the D2D network, then they will be served by the Base Station.



Protocol Model:



Zipf Distribution:

$$f_i = \frac{i^{-\gamma_r}}{H(\gamma_r, 1, m)}$$

$$H(\gamma, a, b) = \sum_{i=a}^{b} \frac{1}{i^{\gamma}} \qquad i = 1, \cdots, m$$

Problem Definition

- Our goal is find the maximum throughput of D2D network.
- First, we want to find an upper bound of the maximum throughput under the constraint of Protocol Model (channel model) and one-hop transmission
- Second, we want to find an relatively realistic caching policy and transmission scheme to match the upper bound.
- The throughput can be computed as the following.

$$\mathbb{E}[T] = C \cdot \mathbb{E}\left[\text{number of active links}\right]$$

Main Results

- Theorem (achievable bound): Let $m = \Theta(\log n)$. Users make requests with Zipf distribution with parameter 0 < γ_r < 1 and cache a single message, randomly and independently of their location and of their requests, with a Zipf distribution with parameter γ_c. Then, the optimal throughput for the clustering scheme under the Protocol Model behaves as:

$$\mathbb{E}[T] = \Omega\left(\frac{n}{((\log n)(\log\log n))^{\frac{1-\gamma_r}{2-\gamma_r}}}\right)$$

  which is achieved by using γ_c = 1.
- Theorem (Upper bound): Assume $m = \Theta(\log n)$. Users make requests with Zipf distribution with parameter 0 < γ_r < 1 and cache a single message under any caching scheme, the optimal throughput under Protocol Model and one-hop transmission behaves as:

$$\mathbb{E}[T] = O\left(\frac{n}{(\log n)^{\frac{1-\gamma_r}{2-\gamma_r}}}\right)$$

Remark

- An example of m = Θ (log n). Suppose the typical interest of a person spans K files. Then, the typical interest of next person intersects with that of the first person with K/2 files and the incrementally typical interest of the second person spans K/2 files. Similarly, the incrementally typical interest of the third person spans K/3 files and so on. Eventually, the union of all files which people are interested in is m = K +K/2+K/3+K/4+· · ·+K/n = Θ (log n).
- Our scheme is very practical. We do not need any completed coding scheme for files and only need the rank of files, not distribution.

Contact information, sponsors etc.

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