

CS276

Lecture 14

Crawling and web indexes

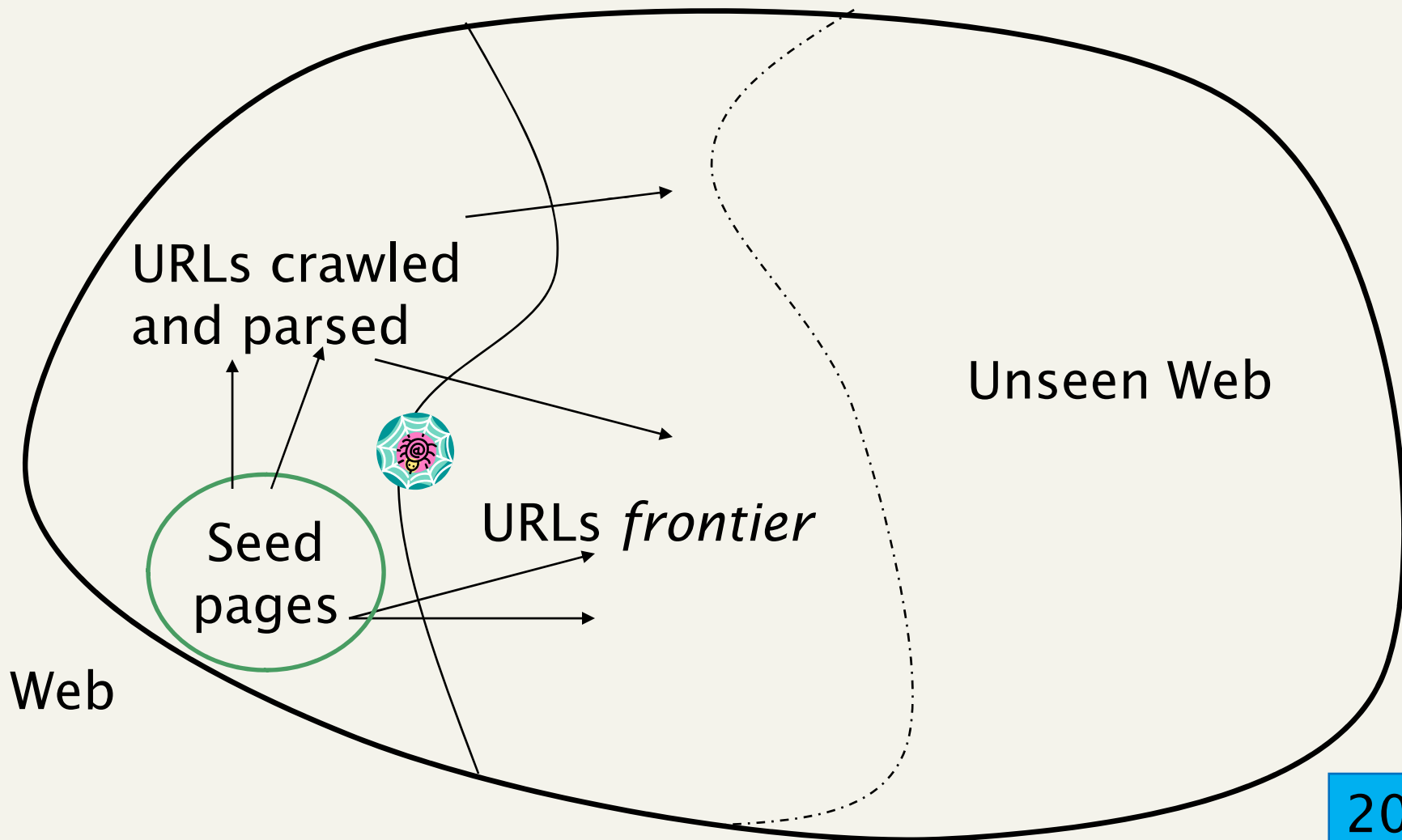
Today's lecture

- Crawling
- Connectivity servers

Basic crawler operation

- Begin with known “seed” pages
- Fetch and parse them
 - Extract URLs they point to
 - Place the extracted URLs on a queue
- Fetch each URL on the queue and repeat

Crawling picture



Simple picture – complications

- Web crawling isn't feasible with one machine
 - All of the above steps distributed
- Even non-malicious pages pose challenges
 - Latency/bandwidth to remote servers vary
 - Webmasters' stipulations
 - How "deep" should you crawl a site's URL hierarchy?
 - Site mirrors and duplicate pages
- Malicious pages
 - Spam pages
 - Spider traps – incl dynamically generated
- Politeness – don't hit a server too often

What any crawler *must* do

- Be Polite: Respect implicit and explicit politeness considerations
 - Only crawl allowed pages
 - Respect *robots.txt* (more on this shortly)
- Be Robust: Be immune to spider traps and other malicious behavior from web servers

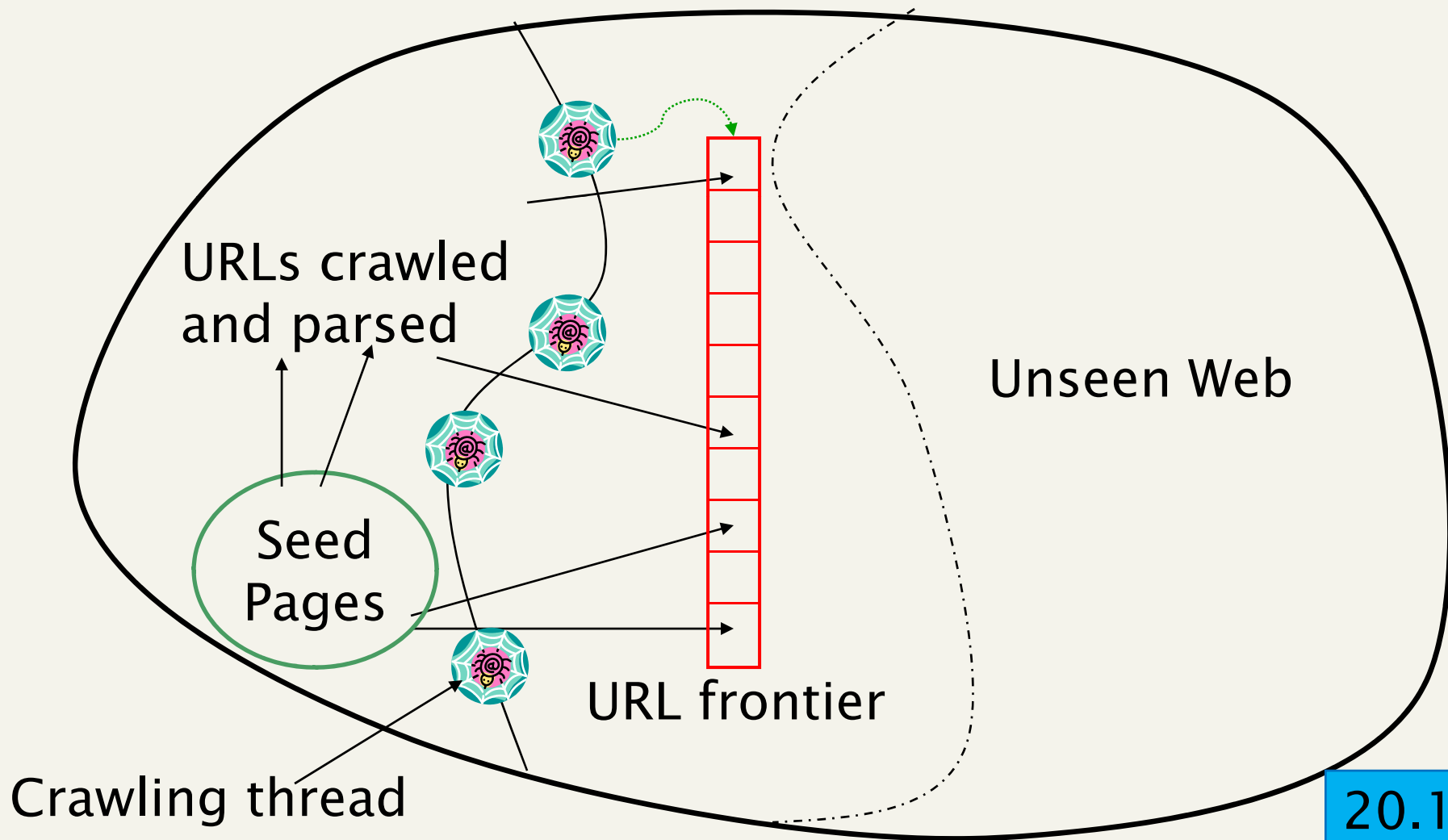
What any crawler *should* do

- Be capable of distributed operation: designed to run on multiple distributed machines
- Be scalable: designed to increase the crawl rate by adding more machines
- Performance/efficiency: permit full use of available processing and network resources

What any crawler *should* do

- Fetch pages of “higher quality” first
- Continuous operation: Continue fetching fresh copies of a previously fetched page
- Extensible: Adapt to new data formats, protocols

Updated crawling picture



URL frontier

- Can include multiple pages from the same host
- Must avoid trying to fetch them all at the same time
- Must try to keep all crawling threads busy

Explicit and implicit politeness

- Explicit politeness: specifications from webmasters on what portions of site can be crawled
 - robots.txt
- Implicit politeness: even with no specification, avoid hitting any site too often

Robots.txt

- Protocol for giving spiders (“robots”) limited access to a website, originally from 1994
 - www.robotstxt.org/wc/norobots.html
- Website announces its request on what can(not) be crawled
 - For a URL, create a file
URL/robots.txt
 - This file specifies access restrictions

Robots.txt example

- No robot should visit any URL starting with "/yoursite/temp/", except the robot called "searchengine":

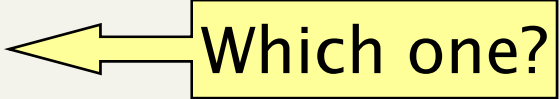
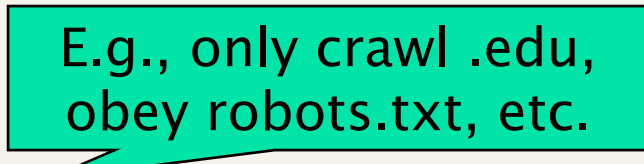
```
User-agent: *
```

```
Disallow: /yoursite/temp/
```

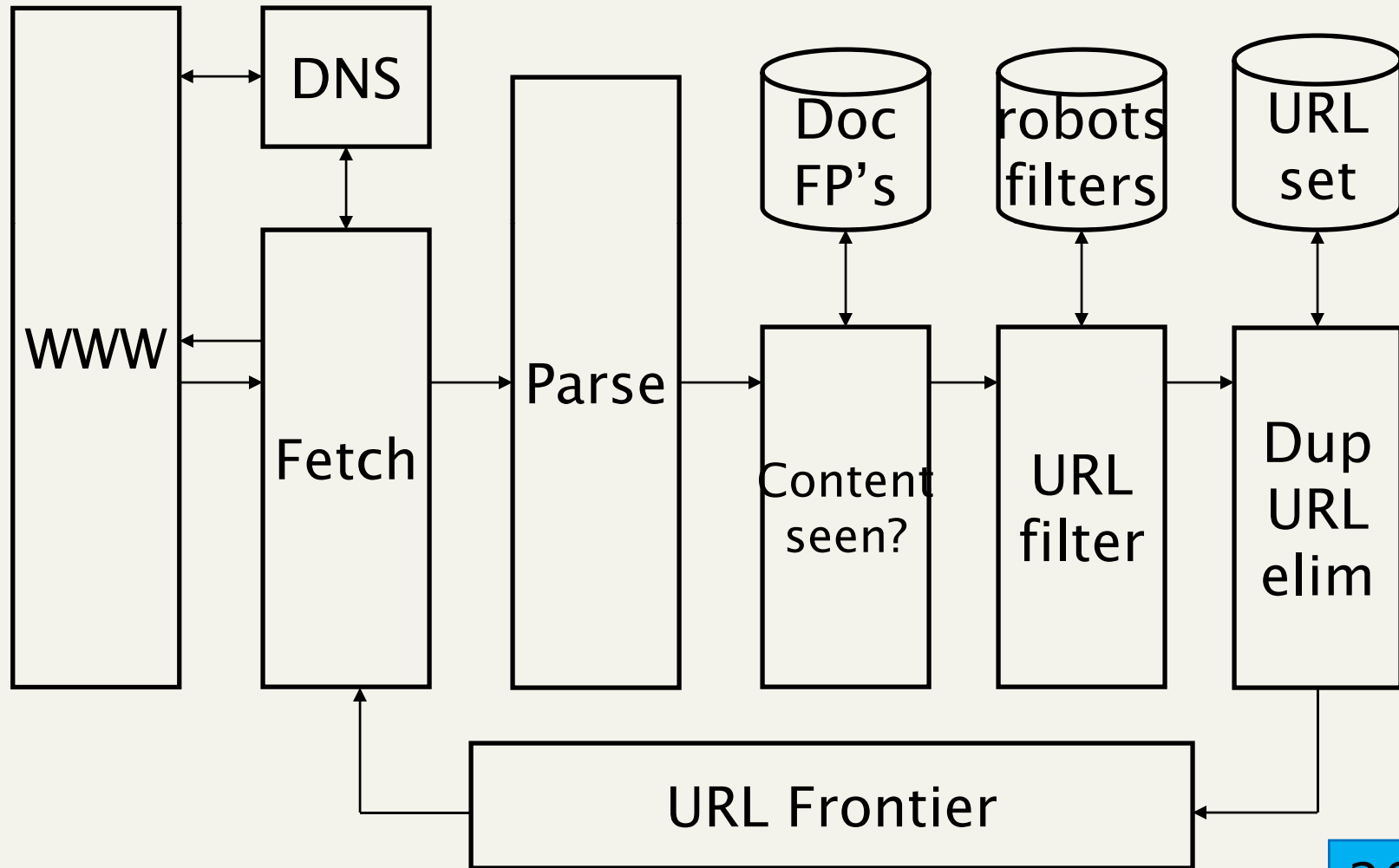
```
User-agent: searchengine
```

```
Disallow:
```

Processing steps in crawling

- Pick a URL from the frontier  Which one?
- Fetch the document at the URL
- Parse the URL
 - Extract links from it to other docs (URLs)
- Check if URL has content already seen
 - If not, add to indexes
- For each extracted URL  E.g., only crawl .edu, obey robots.txt, etc.
 - Ensure it passes certain URL filter tests
 - Check if it is already in the frontier (duplicate URL elimination)

Basic crawl architecture



DNS (Domain Name Server)

- A lookup service on the internet
 - Given a URL, retrieve its IP address
 - Service provided by a distributed set of servers – thus, lookup latencies can be high (even seconds)
- Common OS implementations of DNS lookup are *blocking*: only one outstanding request at a time
- Solutions
 - DNS caching
 - Batch DNS resolver – collects requests and sends them out together

Parsing: URL normalization

- When a fetched document is parsed, some of the extracted links are *relative* URLs

- E.g., at

http://en.wikipedia.org/wiki/Main_Page

we have a relative link to

`/wiki/Wikipedia:General_disclaimer` which is the same as the absolute URL

http://en.wikipedia.org/wiki/Wikipedia:General_disclaimer

- During parsing, must normalize (expand) such relative URLs

Content seen?

- Duplication is widespread on the web
- If the page just fetched is already in the index, do not further process it
- This is verified using document fingerprints or shingles

Filters and robots.txt

- Filters – regular expressions for URL's to be crawled/not
- Once a robots.txt file is fetched from a site, need not fetch it repeatedly
 - Doing so burns bandwidth, hits web server
- Cache robots.txt files

Duplicate URL elimination

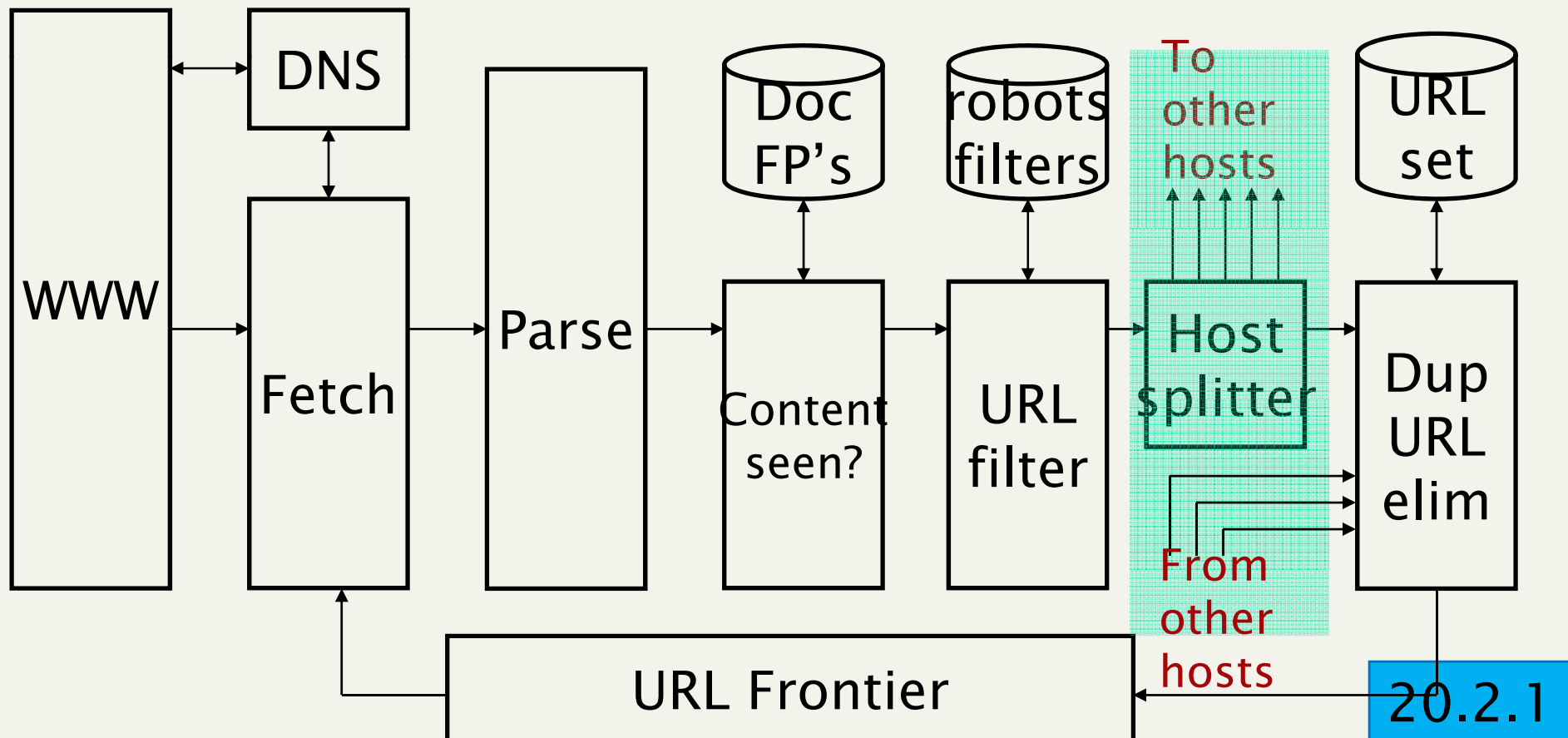
- For a non-continuous (one-shot) crawl, test to see if an extracted+filtered URL has already been passed to the frontier
- For a continuous crawl – see details of frontier implementation

Distributing the crawler

- Run multiple crawl threads, under different processes – potentially at different nodes
 - Geographically distributed nodes
- Partition hosts being crawled into nodes
 - Hash used for partition
- How do these nodes communicate?

Communication between nodes

- The output of the URL filter at each node is sent to the Duplicate URL Eliminator at all nodes



URL frontier: two main considerations

- Politeness: do not hit a web server too frequently
- Freshness: crawl some pages more often than others
 - E.g., pages (such as News sites) whose content changes often

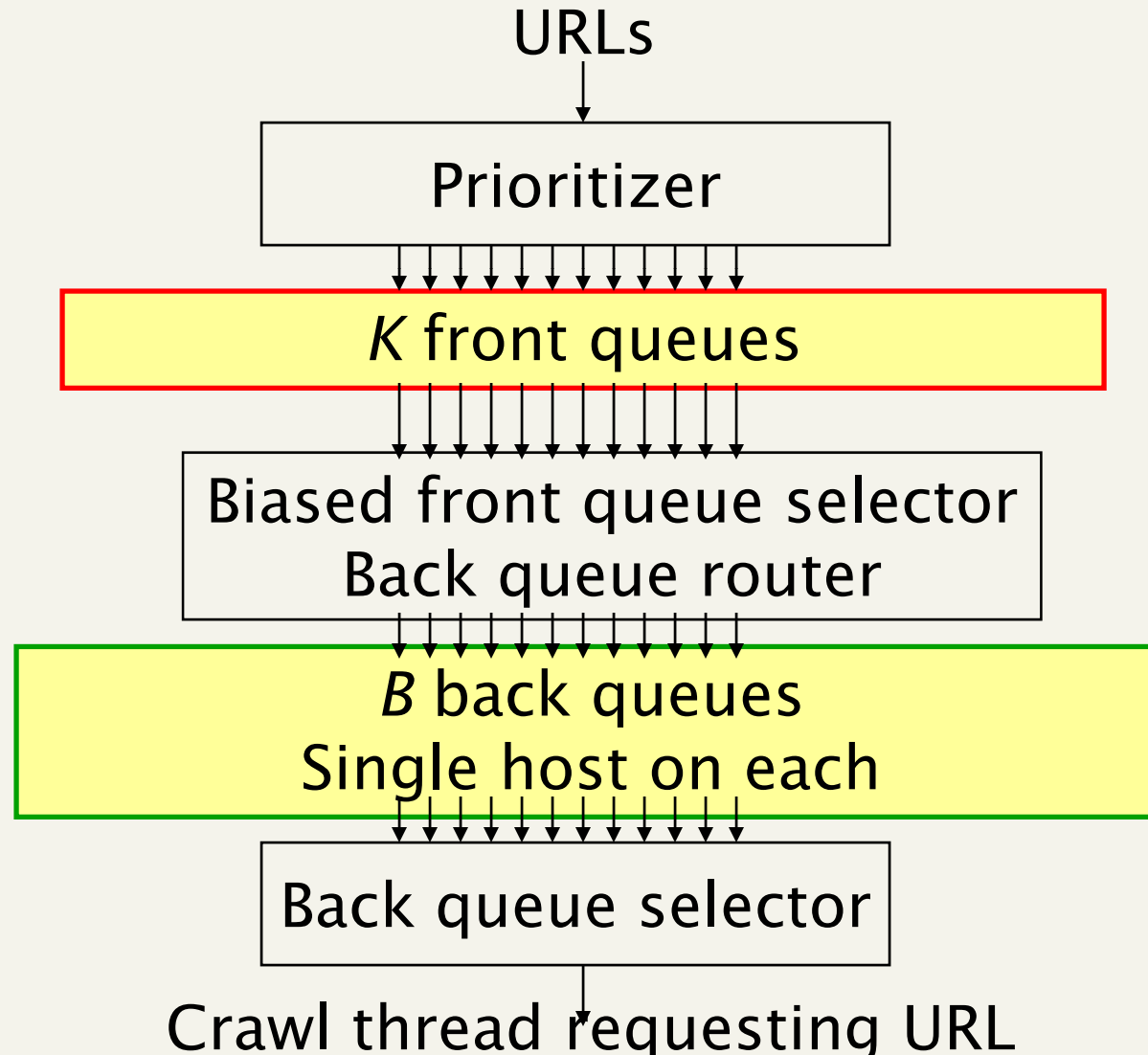
These goals may conflict each other.

(E.g., simple priority queue fails – many links out of a page go to its own site, creating a burst of accesses to that site.)

Politeness – challenges

- Even if we restrict only one thread to fetch from a host, can hit it repeatedly
- Common heuristic: insert time gap between successive requests to a host that is \gg time for most recent fetch from that host

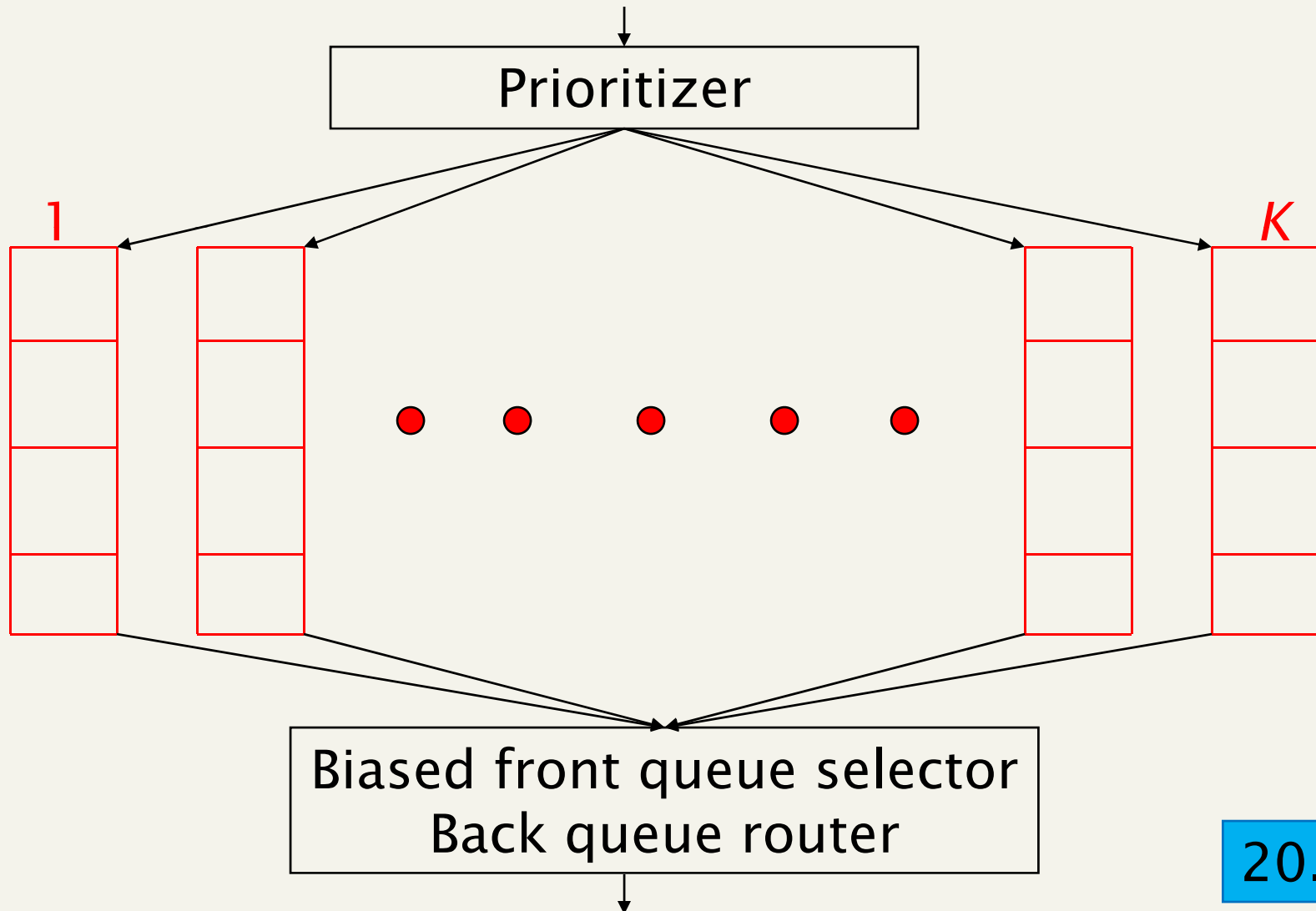
URL frontier: Mercator scheme



Mercator URL frontier

- URLs flow in from the top into the frontier
- **Front queues** manage prioritization
- **Back queues** enforce politeness
- Each queue is FIFO

Front queues



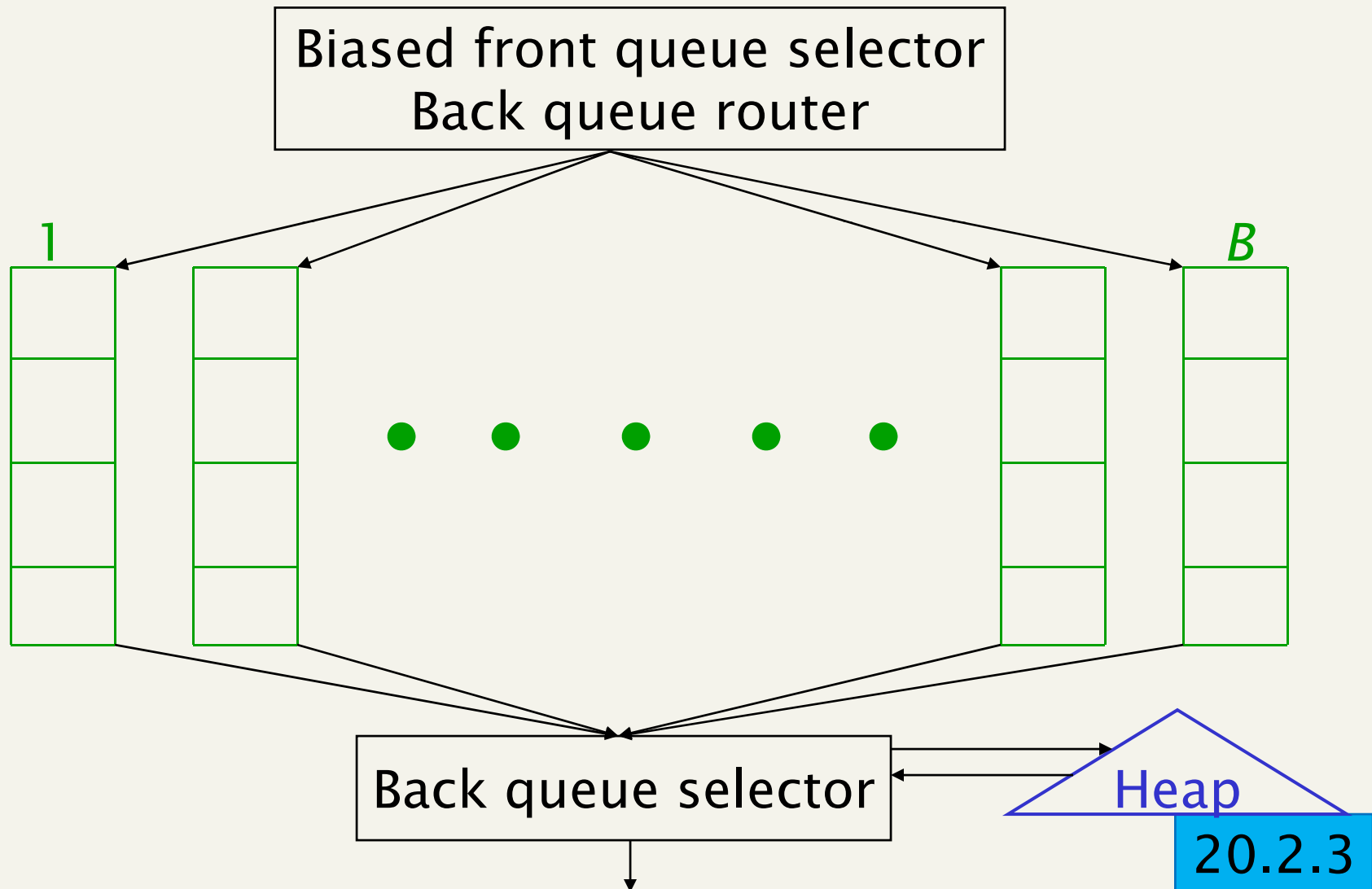
Front queues

- Prioritizer assigns to URL an integer priority between 1 and K
 - Appends URL to corresponding queue
- Heuristics for assigning priority
 - Refresh rate sampled from previous crawls
 - Application-specific (e.g., “crawl news sites more often”)

Biased front queue selector

- When a back queue requests a URL (in a sequence to be described): picks a **front queue** from which to pull a URL
- This choice can be round robin biased to queues of higher priority, or some more sophisticated variant
 - Can be randomized

Back queues



Back queue invariants

- Each back queue is kept non-empty while the crawl is in progress
- Each back queue only contains URLs from a single host
 - Maintain a table from hosts to back queues

Host name	Back queue
...	3
	1
	<i>B</i>

Back queue **heap**

- One entry for each back queue
- The entry is the earliest time t_e at which the host corresponding to the back queue can be hit again
- This earliest time is determined from
 - Last access to that host
 - Any time buffer heuristic we choose

Back queue processing

- A crawler thread seeking a URL to crawl:
- Extracts the root of the heap
- Fetches URL at head of corresponding back queue q (look up from table)
- Checks if queue q is now empty – if so, pulls a URL v from front queues
 - If there's already a back queue for v 's host, append v to q and pull another URL from front queues, repeat
 - Else add v to q
- When q is non-empty, create heap entry for it

Number of back queues B

- Keep all threads busy while respecting politeness
- Mercator recommendation: three times as many back queues as crawler threads

Connectivity servers

Connectivity Server

[CS1: Bhar98b, CS2 & 3: Rand01]

- Support for fast queries on the web graph
 - Which URLs point to a given URL?
 - Which URLs does a given URL point to?

Stores mappings in memory from

- URL to outlinks, URL to inlinks

- Applications
 - Crawl control
 - Web graph analysis
 - Connectivity, crawl optimization
 - Link analysis

Champion published work

- Boldi and Vigna
 - <http://www2004.org/proceedings/docs/1p595.pdf>
- Webgraph – set of algorithms and a java implementation
- Fundamental goal – maintain node adjacency lists in memory
 - For this, compressing the adjacency lists is the critical component

Adjacency lists

- The set of neighbors of a node
- Assume each URL represented by an integer
- E.g., for a 4 billion page web, need 32 bits per node
- Naively, this demands 64 bits to represent each hyperlink

Adjacency list compression

- Properties exploited in compression:
 - Similarity (between lists)
 - Locality (many links from a page go to “nearby” pages)
 - Use gap encodings in sorted lists
 - Distribution of gap values

Storage

- Boldi/Vigna get down to an average of ~3 bits/link
 - (URL to URL edge) Why is this remarkable?
 - For a 118M node web graph
- How?

Main ideas of Boldi/Vigna

- Consider lexicographically ordered list of all URLs, e.g.,
 - www.stanford.edu/alchemy
 - www.stanford.edu/biology
 - www.stanford.edu/biology/plant
 - www.stanford.edu/biology/plant/copyright
 - www.stanford.edu/biology/plant/people
 - www.stanford.edu/chemistry

Boldi/Vigna

- Each of these URLs has an adjacency list Why 7?
- Main idea: due to templates, the adjacency list of a node is similar to one of the 7 preceding URLs in the lexicographic ordering
- Express adjacency list in terms of one of these
- E.g., consider these adjacency lists
 - 1, 2, 4, 8, 16, 32, 64
 - 1, 4, 9, 16, 25, 36, 49, 64
 - 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144
 - 1, 4, 8, 16, 25, 36, 49, 64

Encode as (-2), remove 9, add 8

Resources

- IIR Chapter 20
- [Mercator: A scalable, extensible web crawler \(Heydon et al. 1999\)](#)
- [A standard for robot exclusion](#)
- [The WebGraph framework I: Compression techniques \(Boldi et al. 2004\)](#)