Searching the Internet

Internet Technologies and Applications

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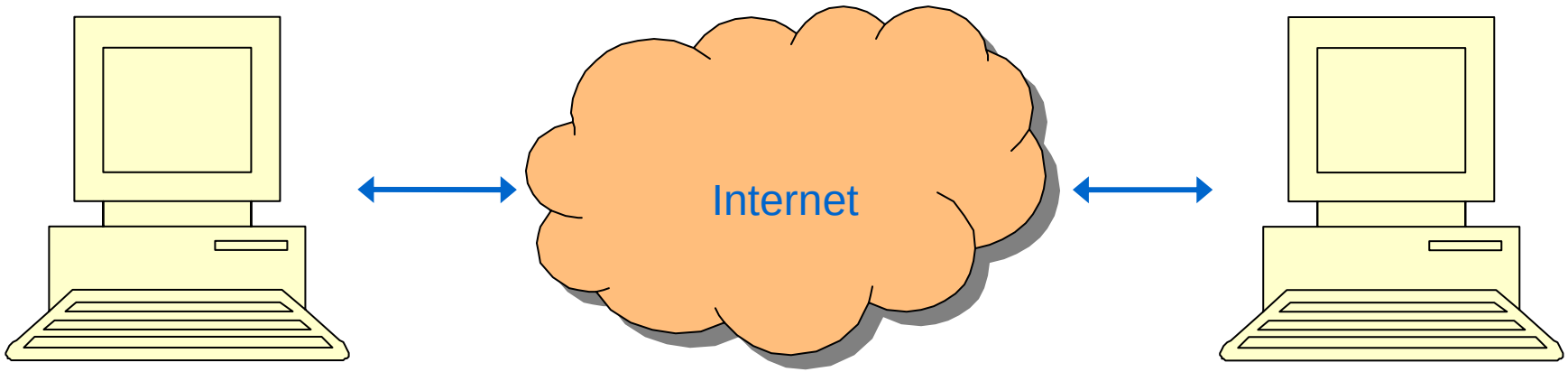
Refresher on Web Site Structure



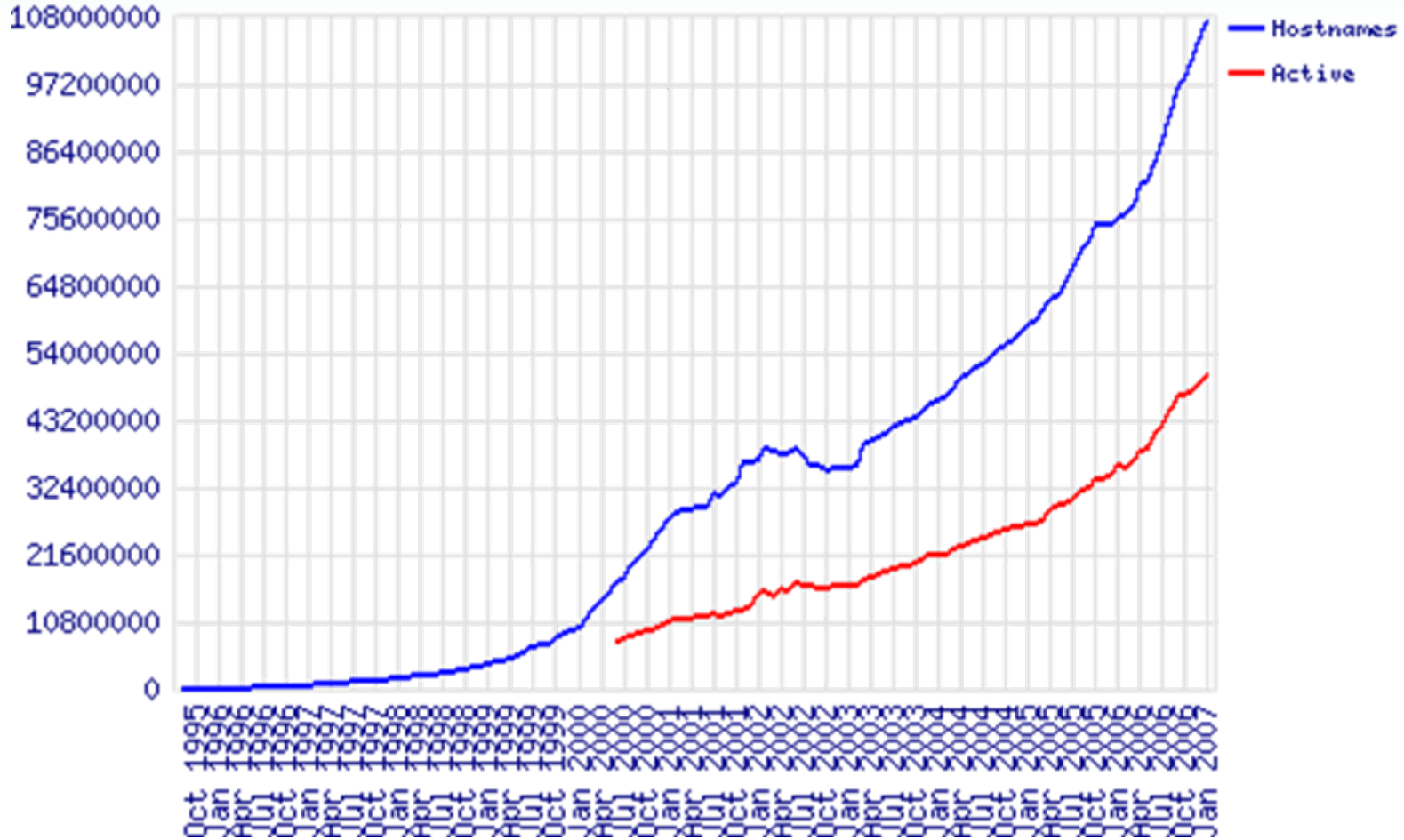
Web Browser (client)

Web Server

- User enters URL (or clicks on link)
- Browsers sends HTTP GET request to that IP address for URL
- Upon receiving HTTP REPLY, browser renders the HTML code to display the content to user

- Server passively listens for connections
- Pages (content) are stored in directories
- Upon receiving HTTP GET request, server retrieves the page and sends to client

Number of Web Servers



Source: January 2007 Netcraft Web Server Survey: www.netcraft.com

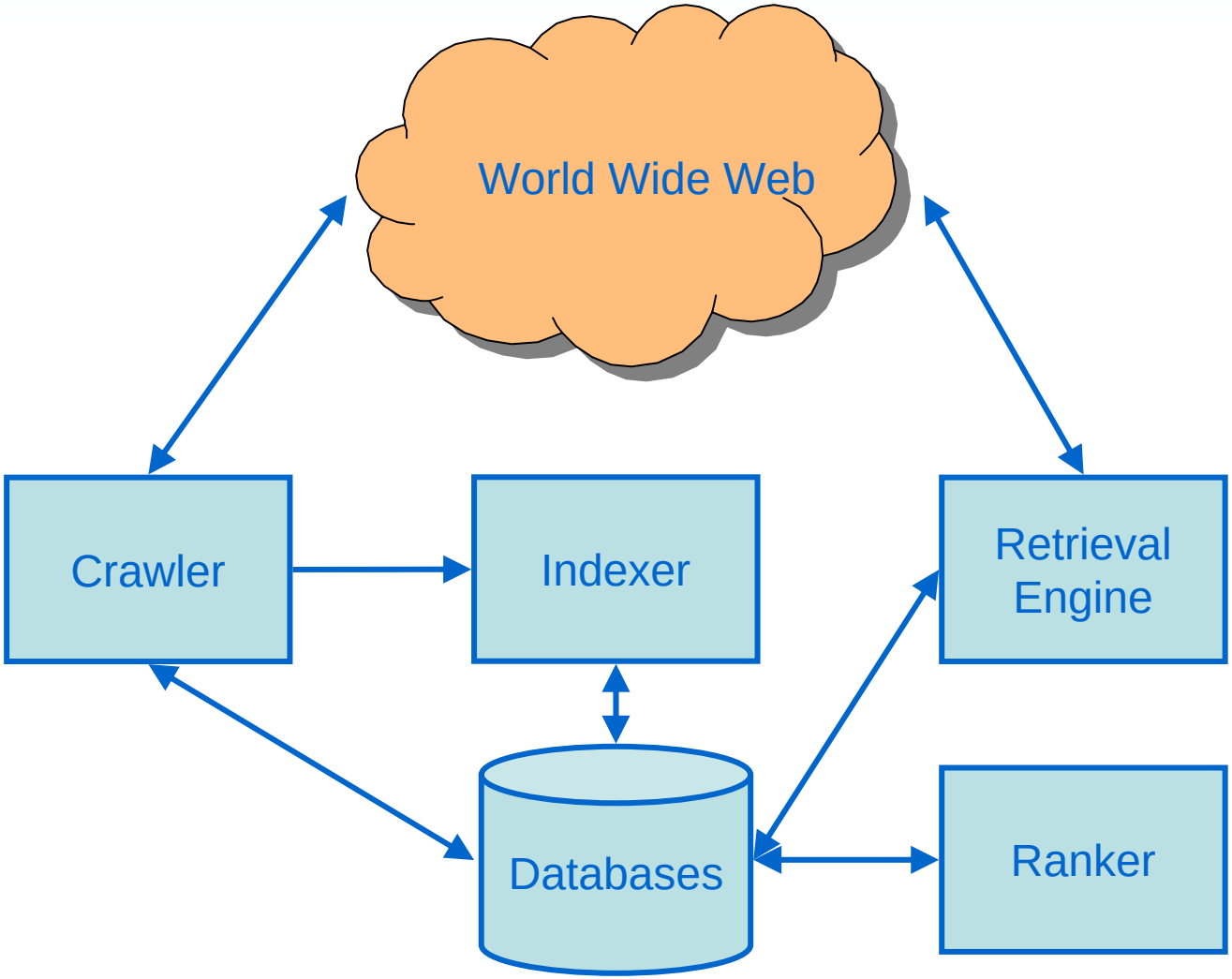
Number of Web Pages

- Indexed by search engines
  - 3-10 billion pages each
    - Hard to find accurate statistics
    - “Indexing” a page may mean different things in different search engines
- Some estimates say search engines only gather about 30% of all pages
  - And many search engines overlap each other

Search Engines and Directories

- Internet Directories
  - Manual (or semi-manual) construction
    - Pages are categorized and reviewed
  - Examples: Yahoo, DMOZ/Open Directory Project, WWW Virtual Library, …
- Search Engines
  - Automatic indexing of pages
    - Crawler visits web pages
  - Examples: Google, Windows Live Search, Yahoo! Search, …
- In practice – a combination of directories and search
  - Most directories include a search feature
  - Most search engines promote directories

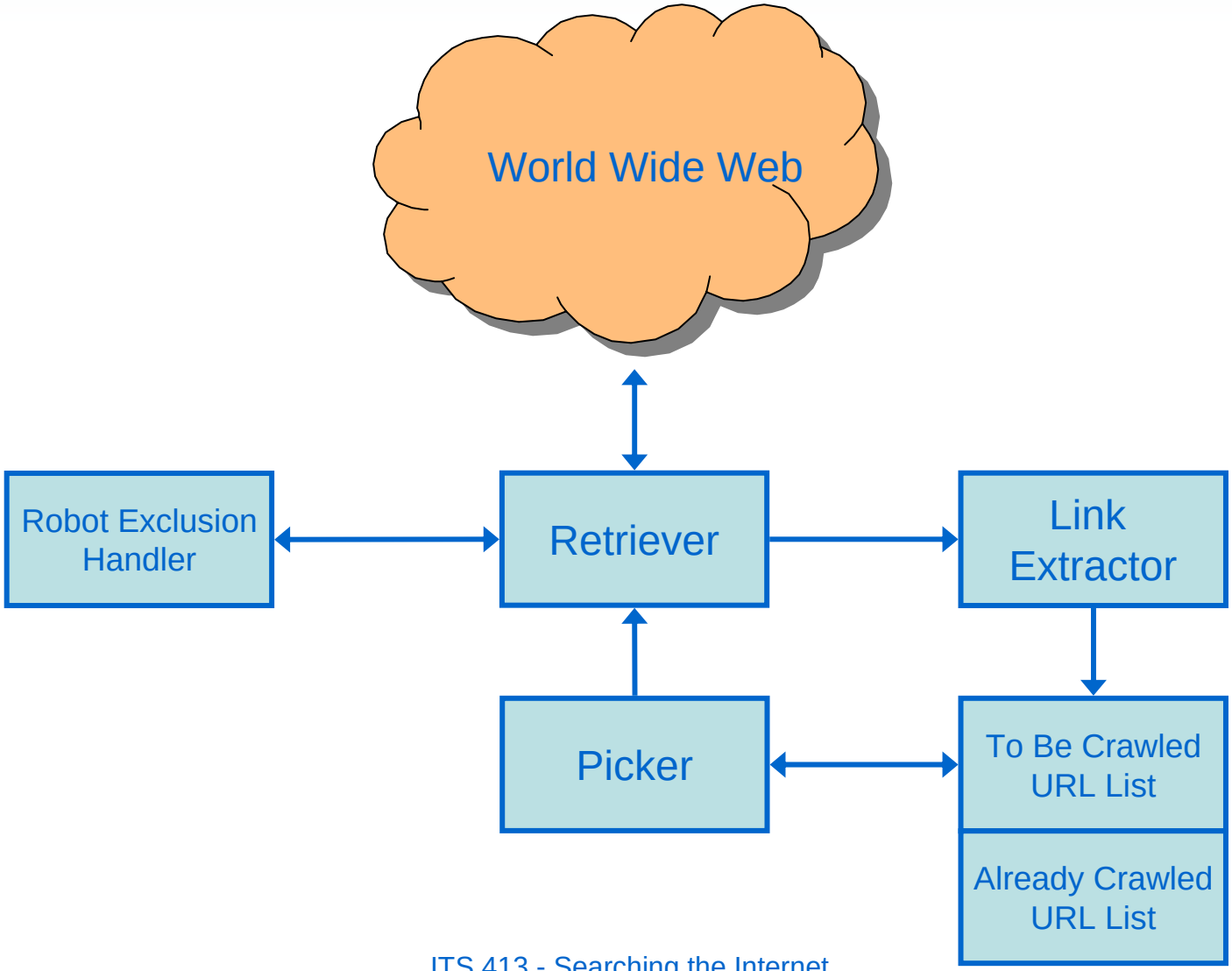
Search Engine Architecture



Crawler

- Also known as:
  - Robots, spiders, worms, walkers, wanderers, …
  - Implementations: Googlebot, Yahoo Slurp, MSNBot,
- Discovers information on the web
  - Starts with a list of seed URLs
  - Visits a page at a seed URL
  - Follows links found in each page it visits
- Aim of a good crawler:
  - Find as many pages as possible in a given time
- Design issues:
  - A problem for crawlers:
    - Number of pages in the Internet is too large to visit them all
    - The pages are always changing (modified, created, deleted)
  - Therefore a crawler cannot visit all pages
  - The solution:
    - Aim to visit the most useful pages within a given time

Crawler Architecture



Crawler: Lists of URLs

- A crawler keeps two lists of URLs:
  - Pages it has yet to visit
    - Initialised with the seed URLs
    - Seed URLs should be popular pages with many outgoing links
  - Pages that have already been visited

- Performance of URL lists
  - Crawler may have billions of URLs in lists, representing gigabytes of memory
  - Store URL lists on disk and cache commonly used URLs in memory

Crawler: Picker

- Must pick the next URL to be visited from “To be Crawled” list
- Why is picking the next URL is so important?
  - A practical crawler cannot visit all URLs; need to select the most useful URLs
- Picking the next URL:
  - Breadth First Search (BFS)
    - Pick a URL from a site that has not been visited yet
    - Provides coverage of a small portion of a large number of sites
  - Depth First Search (DFS)
    - Pick a URL from the current site
    - Provides coverage of a small number of sites, but in great detail
  - Reputation-based
    - Pick a URL with the highest “reputation”
    - Reputation: can be based on links between pages (e.g. more links to a page, the higher reputation the page has) – covered later in ranking
    - Requires crawler to continuously re-calculate the reputation as it discovers new page
      - Increased computing power needed

Crawler: Retriever

- Once picker selects a URL, retriever request page from server
- Multiple retrievers work in parallel
  - Maximise the efficiency of using the network
  - BUT must consider impact on web server
    - Two many concurrent requests on a web server can overload it
    - Good crawlers will have concurrent requests to *different* web servers
      - A single web server will only have one request at a time
      - There will be reasonable delays between subsequent requests to the same server

Crawler: Link Extractor

- Once the page is retrieved, must extract links from that page
  - Must first identify the type of document: HTML, Word, PDF, …
  - A parser for specific document type extracts link from the document
    - Parser can be simple enough to just handle links (for example, does not have to parse <h1> tags)
    - But a good parser can handle incomplete or erroneous document types (e.g. an incorrectly structured HTML page)

Crawlers and Robot Exclusion

- Webmasters may not want all of their website indexed by a crawler
  - Contains private data; crawlers accessing many files may cause performance problems
- Robot Exclusion Protocol (www.robots.txt)
  - A file robots.txt in a web directory is read by a crawler
  - A “good” crawler will follow instructions of the file
    - E.g. do not crawl these directories
  - Similar functionality can be obtained using a META tag in the actual web page
  - Robots.txt file has very simple format
    - Does not allow for complex combinations of files to be specified (e.g. wildcards)
  - Relies on crawlers to follow the standard (that is, to be “good”):
    - Nothing to stop a crawler from not reading or following the robots.txt file
- More secure protection of content is achieved using password protection

Robot Exclusion Example

- Using file: `http://www.domain.com/robots.txt`
  - Disallow all crawlers from accessing a directory:

```
User-agent: *
Disallow: /private-directory/
```

  - Disallow specific crawlers from specific files:

```
User-agent: GoogleBot
Disallow: /~joe/private.html
Disallow: /~joe/foo.html
Disallow: /~joe/bar.html
```

- Using META tag in the HTML file:

```
<html>
<head>
<meta name="robots" content="noindex,nofollow">
<meta name="description" content="This page ....">
<title>...</title>
</head>
<body>
 ...
```

  - “index” = allowed to index this page; “follow” = allowed to follow links on this page (and opposite for “noindex”, “nofollow”)

Indexer

- Index contains the content extracted from the crawled web pages
- The Indexer must process the web page (document) and extract the content
  - Indexing can be performed in parallel with crawling
  - Indexing is very computation and memory intensive
    - Must process billions of pages, and store content extracted from those pages
- Parsing (or pre-processing) the document
  - Must determine which parts (words) of the document best determine its content
  - Limit the number of indexed words per document (to save space)
  - Omit common or non-descriptive words (e.g. “the”, “and”, “I”)
  - Using stemming of words: “reformulation”, “reformative” both indexed as “reform”
  - Output of parsing: list of words for document, and for each word, a description of where it is found (e.g. in title, heading, link)
- The content indexed varies across search engines

Ranking

- With index, a user can submit a query and find all documents with given words
  - Millions of documents returned therefore, not practical; a user wants the documents to be ranked in order of relevance
- Relevance ranking can be:
  - Connectivity-based: number of links to/from the page; number of times page is accessed
  - Content-based: number, frequency and location of terms (words) in document and index
    - Term Frequency: Documents with more occurrences of search word relative to document length receive higher weight
    - Term Location: Terms in title, headings, links (href), figures, metatags may receive higher weight than terms in text
    - Proximity: Terms of a phrase that are close together in document gives higher weight
- Ranking formula:
  - Differs among search engines
  - Kept secret by search engines
    - So webmasters cannot unfairly get their sites higher rankings

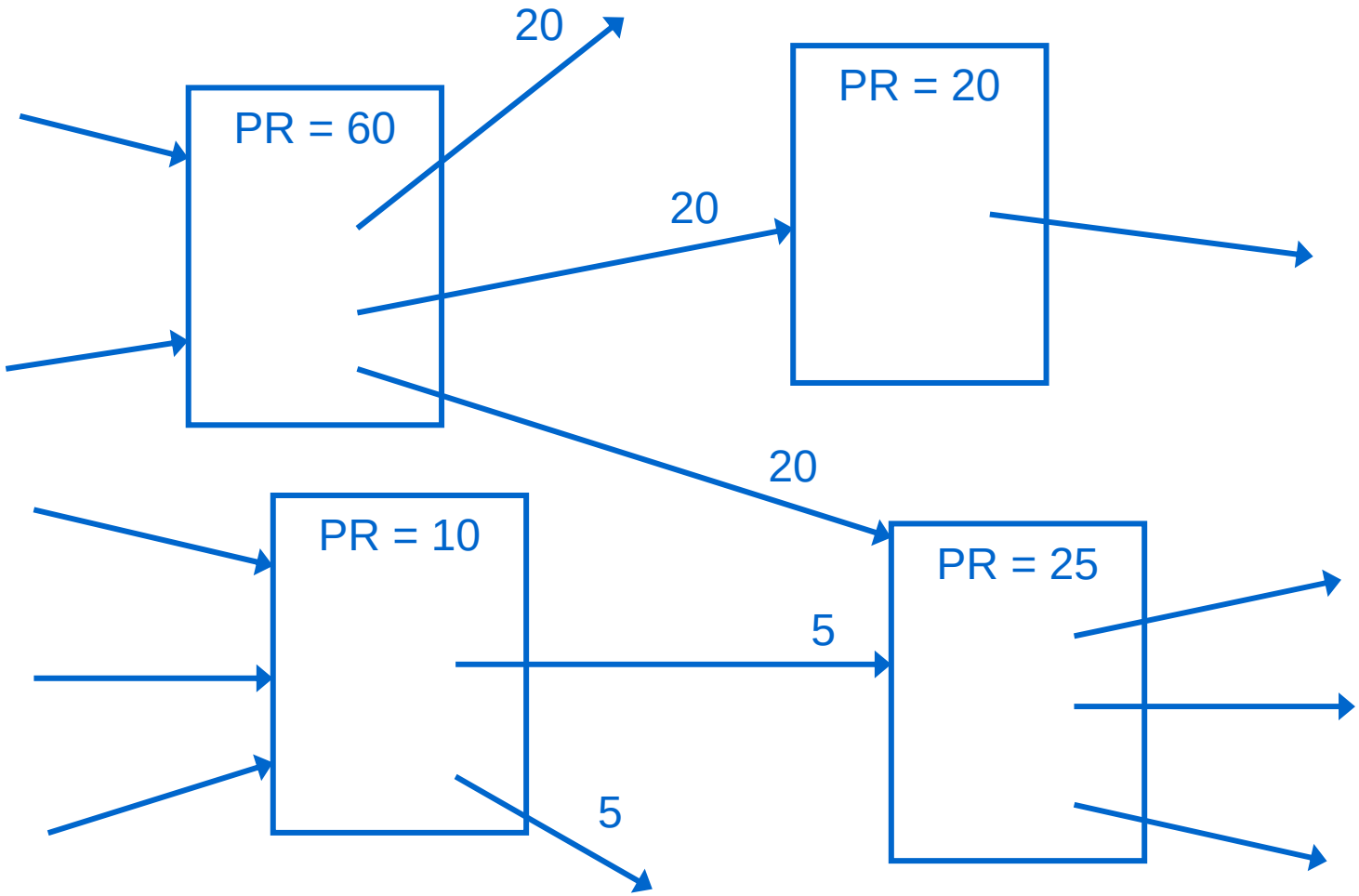
Ranking Techniques

- Query Independent: algorithms used to rank all pages independent of search terms
  - Use counts of links to and from pages; number of accesses
  - Can be pre-calculated (e.g. before a query is run)
- Query Dependent: calculate rank based on content to see how close the documents relate to search terms
  - On-the-fly computation: must be calculated for each search query; resource consuming
- Hubs and Authorities
  - Authority pages are considered a primary source of information (on some topic)
    - E.g. Thammasat University website is an authority on Thammasat
  - Hubs are a collection of links (e.g. Yahoo directory)
  - Ranking is based on:
    - Good authority pages will be linked to from many good hubs
    - Good hubs will link to many good authorities
  - Ranking calculated by analysing links for collection of pages relevant for a query
    - On-the-fly computation
  - Works well; but computation intensive and not efficient enough for large search engines
- Search engines use a combination of approaches

Google PageRank

- Google uses more than 140 criteria to rank pages
  - Exact details and algorithms of criteria is secret
  - PageRank is a key concept used by Google
- PageRank
  - Example of Query-independent (global) ranking
  - Main idea of PageRank:
    - A “web surfer” follows links in pages and calculates rank
    - Number of links to pages will contribute to rank
    - Links from higher ranked pages contribute more than links from lower ranked pages
  - Process is iterative – cycles may occur where the ranks of pages will keep increasing
    - To avoid cycles, sometimes surfer randomly move to another unlinked site
  - Problem with PageRank
    - Newly created pages will not have many links to them – low PageRank
    - Low PageRank for a page means will not be found in search results (and hence hard to get links to the page, i.e. cannot increase PageRank)

Simple PageRank Example



Retrieval Engine

- Combines Index and Ranking to present results to user:
  - Parse the user's search query
    - Remove any common words (e.g. "and", "the")
  - Find relevant documents from Index
  - Rank documents
  - Present results to user

Search Engine Optimisation

- Search engines are the main technique for finding information on the Internet
  - Financial advantages of getting your website ranked highest
    - More people use your products and services
    - You can demand more from advertisers on your site
- Search Engine Optimisation (SEO): Techniques to get your website a higher ranking
  - Good: improve your website and content to suit search engines algorithms
  - Bad: use artificial techniques to get higher ranking than your content deserves!
  - (Distinction between good and bad techniques is more ethical and business oriented)
    - Follow search engine guidelines, do not try to deceive

SEO Techniques

- Many companies offer ways to increase your chances of higher rank
  - Some techniques are not allowed by search engine guidelines
- Basic approach for good ranking
  - Include relevant keywords in:
    - Page title and headings
    - Links from other sites to yours
      - Keywords in your domain/URLs?
    - Page text
  - Have links from other popular sites to yours
- Link exchange
  - Informal exchange between sites (“I will link to yours if you link to mine”)
  - Pay companies and organisations to link to your site

SEO Techniques

- Malicious Techniques
  - Keywords stuffing: Include many (hundreds) keywords in title, metatags, page (including to topics that aren't on your site) (easy to detect)
  - Crawler traps: software/pages that try to keep crawler on site (so crawler thinks its important site (easy to detect)
  - Ghost sites: create many simple one-page sites that link to your site
  - Blogs/Wikis: include many links in blogs/wikis to your website
- Banning Sites
  - Search engines have banned sites (removed from index) if guidelines are not followed
    - BMW and Ricoh were briefly banned in 2006

Improving Search Engines

- New Features and Capabilities:
  - User interface: graphical visualisation of results
  - Metadata: Include more descriptive information about a document; follow W3C standards on metadata
  - Metasearch: search multiple engines at once
    - Problems with determining ranking of results, conflicting ranks of same document, and speed depends on slowest engine
- Research:
  - Including dynamic content in index: database content
  - Peer to peer search: use peers to do crawling and indexing
    - Can be very slow in getting responses to queries
  - Semantic Web: better ways for describing and searching based on the meaning of content