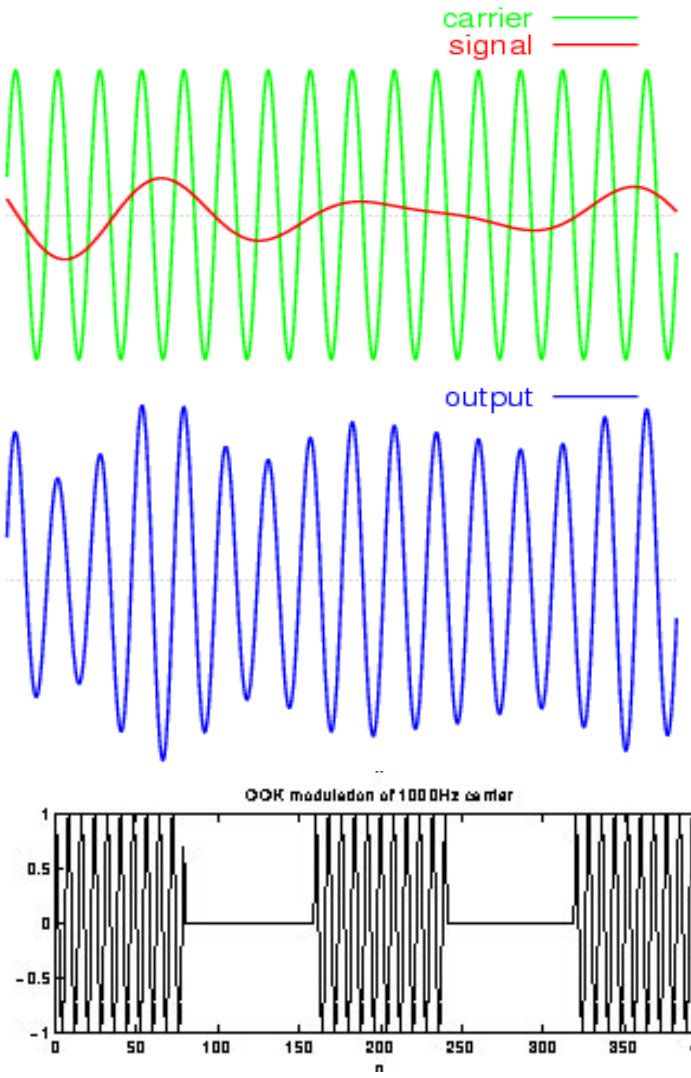
Wireless systems

- **how radio works**
- **radio spectrum allocation**
- **examples**
  - cell phones
  - 802.11 (WiFi)
  - Bluetooth
  - GPS
  - RFID: prox, E-ZPass, store tags, passports, ...
  - ...
- **tradeoffs**
  - spectrum, power, range, size, weight, mobility
- **non-technical issues**
  - regulation, competition, ...

Radio

- **electromagnetic radiation to carry information**
  - without wires => "wireless"
- **radiation is a wave of a particular frequency (in Hz)**
- **"modulate" the wave to impose information on it**
  - amplitude (AM): change the power level
  - frequency (FM): change the frequency around nominal value
  - digital: on/off
  - …
- **received signal strength varies directly with power level**
- **received signal strength dies off with square of distance**
- **higher frequencies go shorter distances**

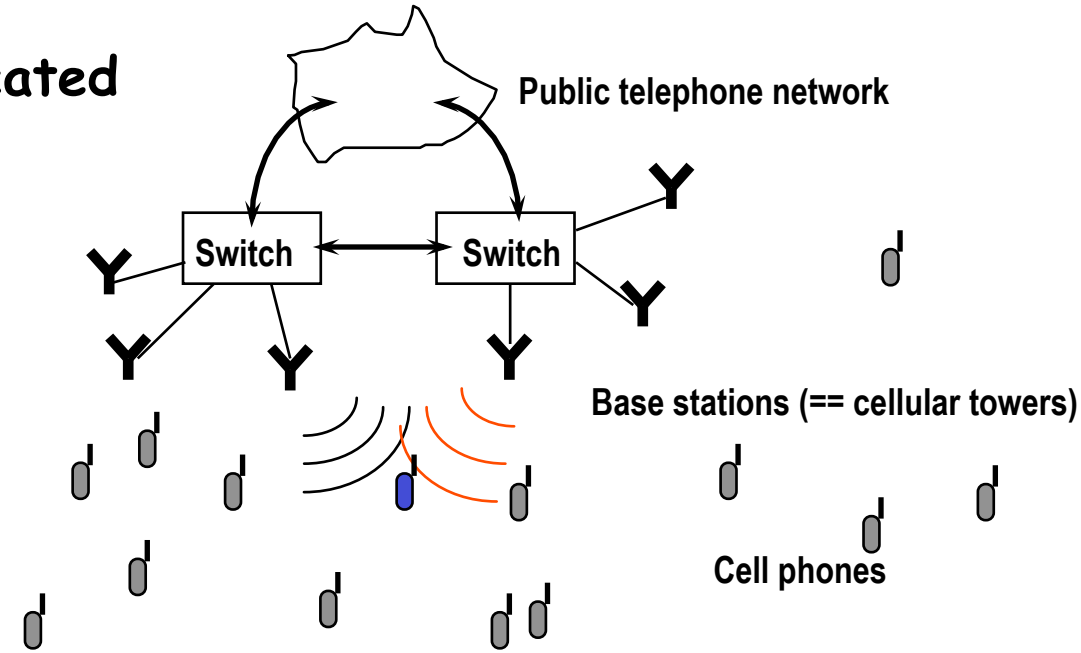


Cell phones 101

- all phones are part of the public switched telephone network
- a cell phone is connected by radio instead of wires

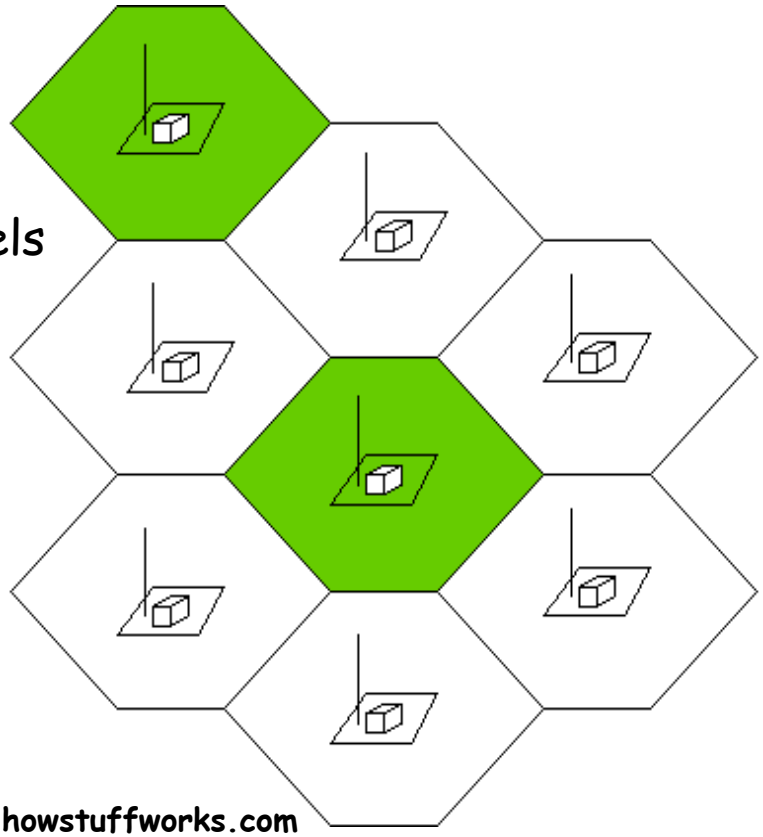
- moves long distances, at high speed, appears out of nowhere
- shares a very limited radio frequency spectrum with others
- operates with low power because it uses batteries

- this makes life complicated



Cells (a very idealized picture)

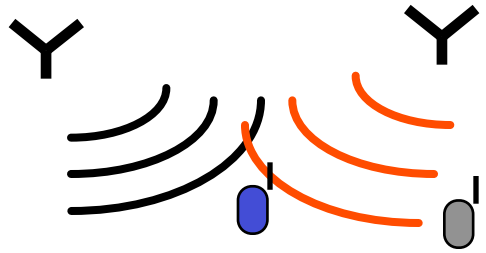
- **divide geographical area into cells (notionally hexagonal)**
- **each cell has an antenna, handles all cell phones in its area**
- **available radio spectrum is divided into channels**
  - two channels for one conversation, one for each direction
  - competing carriers operate on different frequencies
- **each cell gets 1/7 of the channels**
  - adjacent cells can't use the same channels because of interference
  - non-adjacent cells can re-use channels



from www.howstuffworks.com

How it works

- **when a phone is turned on, it broadcasts its ID ("registration")**
  - nearest base station notices, validates with home system
    registration uses encryption for fraud prevention
  - phone keeps broadcasting enough to keep in touch
- **when the phone is called, the home system knows where it is**
  - home system contacts base(s) where phone is
  - bases broadcast to where phone was last seen ("paging")
- **phones talk to base with strongest signal**
  - base and phone communicate over 2 agreed-upon channels (up, down)
  - phones continuously adjust power level to signal strength at base
    uses less battery, creates less interference for other phones
- **phones move from base to base and from system to system**
  - base initiates handoff when signal gets weak
  - phone picked up by base with strongest signal
  - elaborate protocols at all levels



How it works, continued

- **multiple frequency bands (different in different parts of the world)**
  - divided into channels (frequency multiplexing)
    digital phones multiplex several calls on one channel (GSM)
    or spread calls out over the whole spectrum (CDMA)
  - phones usually support multiple bands
- **channels carry both voice and control information (including data)**
  - digital speech is highly compressed (~1 bit/speech sample)
  - elaborate coding & error correction for speech & control information
  - power turned off when nothing is being sent
- **phones store user info on removable flash memory card**
  - SIM (Subscriber Information Module)
  - may be able to replace card to use in a different environment
- **most of the world uses GSM**
  - in USA, AT&T & T-Mobile use GSM; Verizon & Sprint use CDMA

Technology meets politics again

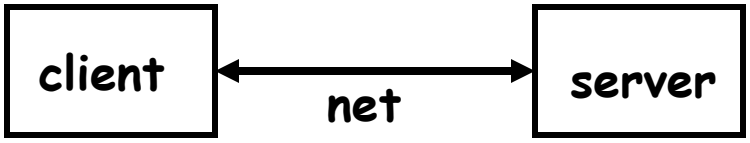
- **should texting while driving be illegal (and enforced)?**
  - how about just talking on a phone while driving?
- **where determines where cell phone towers are permitted?**
  - property rights versus eminent domain
- **should cell phone jammers be legalized?**
  - in theatres, trains, etc.

- **location tracking and surveillance**
  - FCC mandates that cell phone can be locatable within 125 meter radius
  - should real-time location info be available to law enforcement, etc.?
  - how should this evolve as GPS becomes universally available?
  - who can have access to what cell phone records under what circumstances?

GPS (Global Positioning System)

- **31 satellites, each broadcasting time & its location**
  - altitude ~ 20 km, frequency ~ 1575 MHz
  - at least 6 are visible at any time
- **receiver calculates its position using distances to 3 or more satellites**
  - distances computed by careful measurement of time
  - accuracy typically within 15 m for civilian systems
  - additional inputs or use of encrypted info reduces this to < 1 m

Search engines



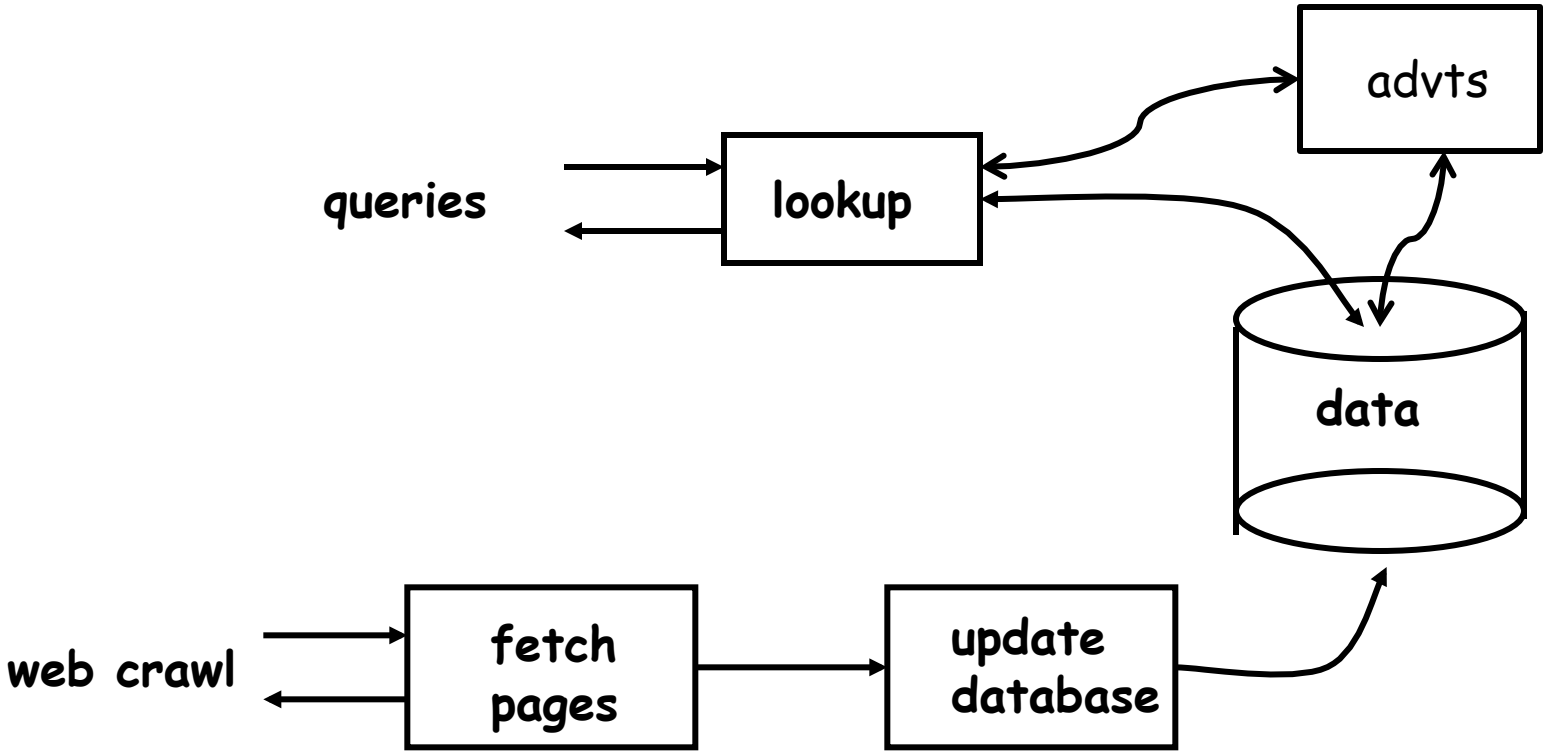
- **browser uses a FORM to send a query to a server**
  - e.g., google.com
- **server runs a program to extract query from form**
- **finds pages that contains word(s) of query**
- **generates HTML**
- **returns page to client**

- **server needs to know what pages contain relevant words**
- **continuously crawls the web collecting pages**
- **builds big database that tells what pages contain any given word**

- **basic problem: scale**
  - lots of pages, lots of words, lots of queries

Server processes

- **3 basic processes going on in parallel**
  - respond to incoming queries by looking up words in database
  - crawl web looking for new pages
  - extract words from new pages and insert into database



Fetching new pages

- **start with a list of likely URLs**
- **fetch data from next URL from the list**
  - obey robot exclusion standard
- **extract parts to be indexed, deliver to index builder**
- **extract URLs**
- **delete duplicate URLs (ones seen recently)**
- **delete irrelevant ones (advertisements, …)**
- **add remaining URLs to end of list**
- **go back to the top**

- **questions:**
  - how to start
  - how to detect duplicates quickly
  - what to preserve (text, .html files, .txt files, PDF, gif/jpg, …)
  - how to avoid overloading big/popular sites

Building and searching an index

- **for a new page that has just been fetched:**
  - isolate words (discard HTML tags, etc.)
  - handle upper and lower case, accents, punctuation, other languages and character sets, ...
  - for each word
    add URL to list for that word
    add word position within the page to the list for the URL

- **to look up a single word query:**
  - go to the list for the word
  - collect all URLs
  - sort them into order by weighting function
    importance, frequency, …
- **queries with multiple words:**
  - collect URL lists, combine them, weight them

Ranking search results

- **how to get the most likely results on the first page (at the top)**
  - most people look only at the first few results
  - need for very high precision (relevant documents in the top 10 or so)

- **Google uses proprietary "page rank" algorithm based on link structure of web**
  - pages that are cited often move higher
  - pages that are cited by higher ranked sites move higher
  - anchor (<a href=...>) text gives more information
  - proximity of search terms within page
  - ...
- **other search engines have analogous techniques**

- **have to defend against attempts to inflate rankings**

Privacy and copyright issues

- **what privacy standards apply to search engines?**
  - how can private / incorrect information be purged?
  - right to be forgotten?
- **search engines versus government**
  - should search engines release information about dissidents to the local government?
  - should search engines suppress / restrict query results if requested by government?
  - can query logs be subpoenaed?
    AOL's release of "sanitized" information permitted identification of individuals from their queries
- **copyright**
  - Viacom v YouTube: vicarious liability or DMCA safe harbor?
  - should newspaper stories be indexed without permission?
- **trademarks**
  - can someone buy someone else's trademark as an advertising keyword?
    e.g., could Microsoft buy "iPad"
- ...

Hardware

- **logical/functional/architectural structure**
  - bus connects CPU, RAM, disks, other devices
  - caching
  - CPU cycle: fetch-decode-execute; kinds of instructions
    toy machine as an example
    different processor families are incompatible at the instruction level
  - von Neumann: architecture; Turing: equivalence of all machines
- **physical implementation; sizes and capacities**
  - chips; Moore's law, exponential growth
- **analog vs digital**
- **representation of information**
  - bits, bytes, numbers, characters, instructions
  - powers of 2; binary and hexadecimal numbers
  - interpretation determined by context
- **it's all bits at the bottom**

Software

- **algorithms: sequence of defined steps that eventually stops**
  - complexity: how number of steps is related to amount of data
    linear: searching, counting, …
    quadratic: simple sorting
    logarithmic: binary search (logarithm = number of bits needed to store)
    n log n: quicksort
    exponential: towers of Hanoi, traveling salesman problem, …
- **programs and programming languages:**
  - evolution, language levels: machine, assembly, higher-level
  - translation/compilation; interpretation
  - a program can simulate a machine or another program
- **basic programming, enough to figure out what some code is doing**
  - variables, constants, expressions, statements, loops & branches (if-else, while), functions, libraries, components
- **operating systems: run programs, manage file system & devices**
  - file systems: logical: directories and files; physical: disk blocks
- **application programs, interfaces to operating system**

Communications

- **local area networks, Ethernet, wireless, broadcast media**
- **Internet: IP addresses, names & DNS, routing; packets**
  - bandwidth
- **protocols: IP, TCP, higher-level; layering**
  - synthesis of reliable services out of unreliable ones

- **Web: URLs, HTTP, HTML, browser**
  - caching
- **security & privacy: viruses, cookies, spyware, …**
  - active content: Javascript, plugins, addons

- **cryptography**
  - secret key; public key; digital signatures; secure hashes
- **compression; error detection & correction**

- **case studies and the real world**
  - prox cards, peer to peer, cell phones, search engines, …

Real world issues

- **legal**
  - intellectual property: patents, copyrights, contracts, licenses
  - jurisdiction, especially international
- **social**
  - privacy, security
- **economic**
  - open source vs proprietary
  - who owns what
- **political**
  - policy issues
  - balancing individual, commercial and societal rights and concerns