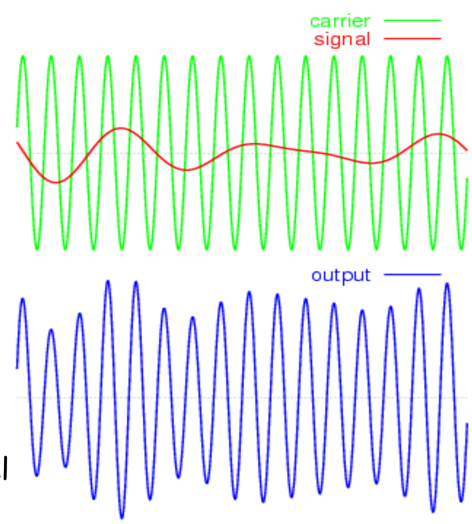
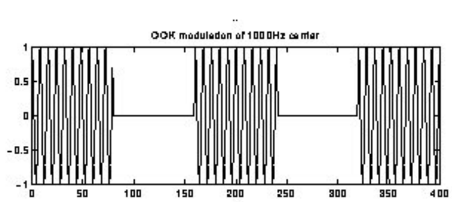
Wireless systems

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

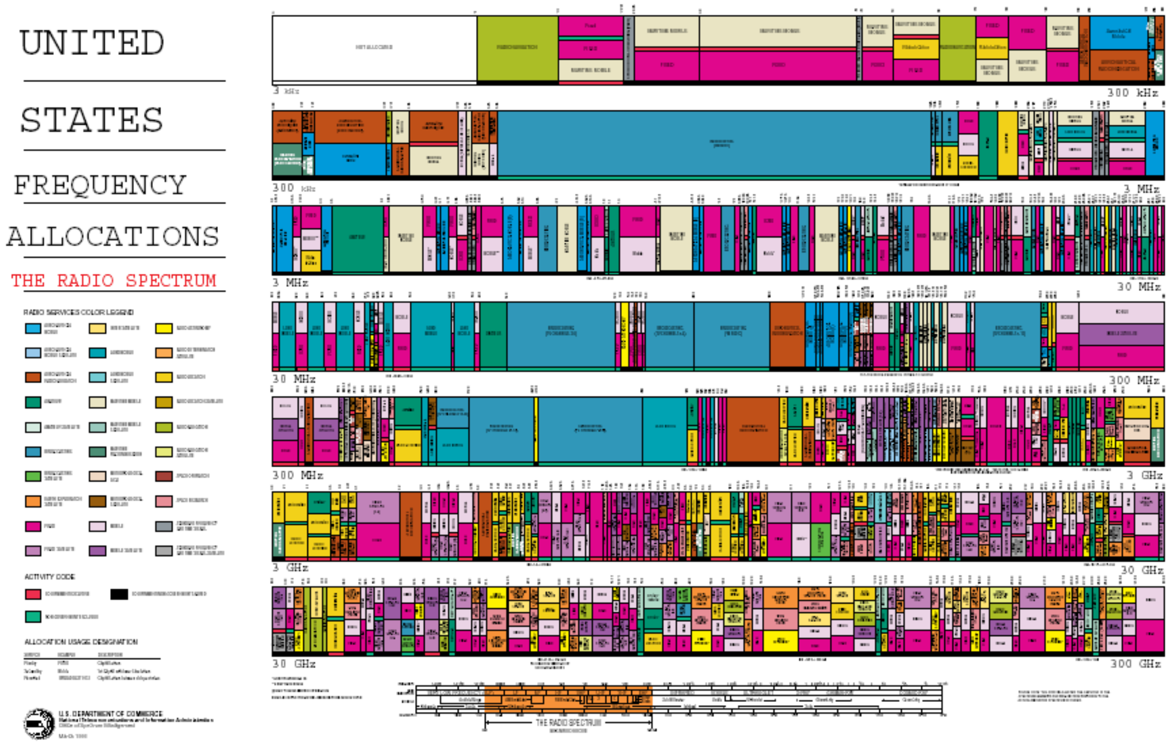
Radio



- **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
  - ,,,
- **received signal strength varies directly with power level**
- **received signal strength dies off with square of distance**
- **higher frequencies go shorter distances**



RF spectrum (http://www.ntia.doc.gov/osmhome/allochrt.pdf)

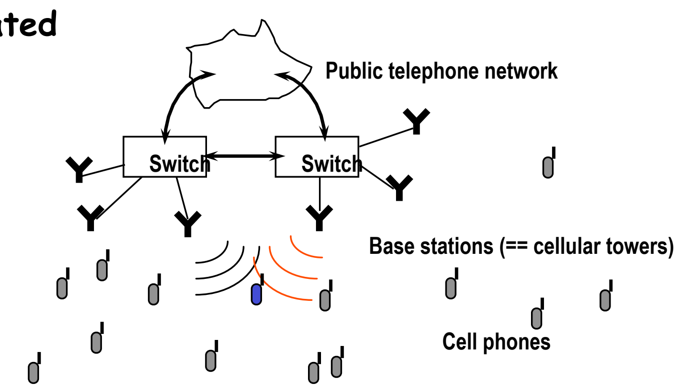


Cell phones 101

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

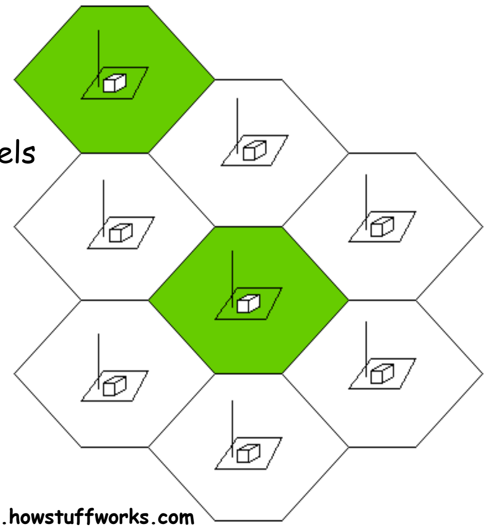
- <u>moves</u> long distances, at high speed, appears out of nowhere
- shares a very limited radio frequency <u>spectrum</u> with others
- operates with low <u>power</u> because it uses batteries

- this makes life complicated



Cells (a very idealized picture)

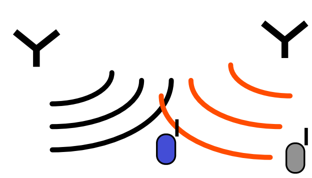
- **divide geographical area into cells (notionally hexagonal)**
- **each cell has an antenna, handles all cell phones in its area**
- **available radio spectrum is divided into channels**
  - two channels for one conversation, one for each direction
  - competing carriers can all operate
  - each has its own independent equipment
- **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
- **when phone is called, home system knows where it is**
  - contacts base(s) where it is
  - bases broadcast to where 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

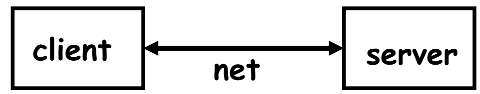
- **multiple frequency bands** **(different in different parts of the world)**
  - divided into channels (frequency multiplexing)
    digital phones multiplex several calls on one channel (GSM)
    or spread calls out over the whole spectrum (CDMA)
  - phones usually support multiple bands
- **channels 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
- **GSM 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 m 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 when?
  - see Carrier IQ flap in Dec 2011

Search engines



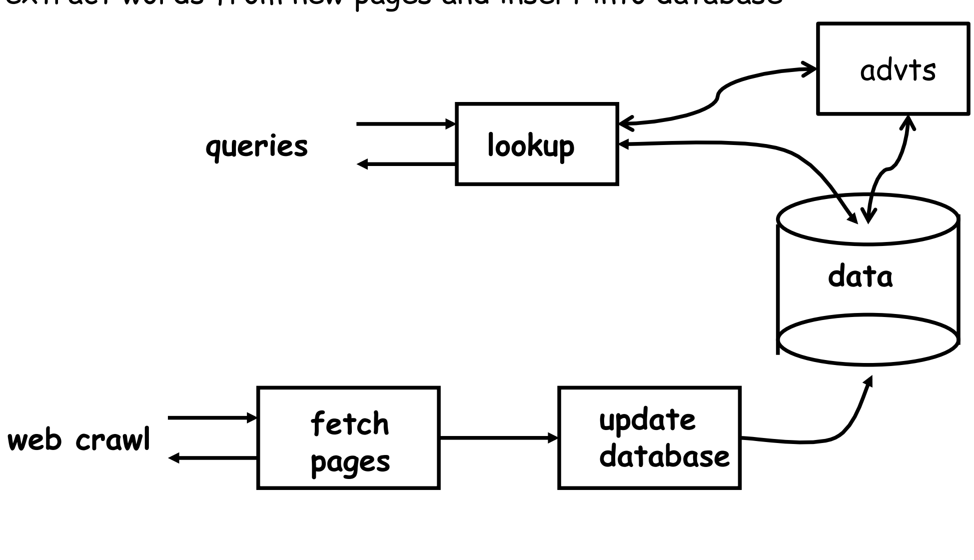
- **browser uses a FORM to send a query to a server**
  - e.g., google.com
- **server runs a program to extract query from form**
- **finds pages that contains word(s) of query**
- **generates HTML**
- **returns page to client**

- **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

Hashing: an algorithm to look things up quickly

- **problem: how to look up one word in 1 billion words, really fast**
  - binary search would be 30 probes ***if*** names were sorted
  - sorting takes too long if it has to be updated

- **hashing: scramble the word into an integer**
  - between 0 and N
  - so that hash values of potential words are spread out uniformly
- **store all words with the same hash value together**
- **searching for a word then requires only**
  - compute the hash value
  - look at the list of previously-stored words with that hash value

- **example hashing algorithm: add up the numeric values of all the characters in the word**

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?
- **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., Microsoft buys "iPod"
- ...

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
- **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

Things to take away

- **some skills, some specific technical knowledge**
  - how computers and communications work today
  - what's ephemeral, what's likely to still be true in the future
- **improved numeracy / quantitative reasoning**
  - what makes sense, what can't possibly make sense, and why
    plausible estimates, engineering judgement, enlightened skepticism
- **another way of thinking**
  - how do things work?
  - how *might* something work?
  - you can often figure it out
- **some appreciation of tradeoffs & alternatives**
  - you never get something for nothing
- **some historical perspective**
  - everything derives from what came before

- **informed opinions about the role of technology**

Final exam (watch the web page!!!)

- **Friday January 27 1:30pm, Friend Center 101**
  - Q/A session January 22?; watch the web page for schedule
  - come to office hours or send mail or drop in; watch the web page
- **similar to midterm but twice as long**
- **open notes, problem sets, labs, text, …**
- **bring a calculator if you can — it might make something easier**
- **hints**
  - I'm usually looking for something brief that shows that you understand or can reason
  - if you're writing or calculating a lot, you're likely on the wrong track
  - questions are meant to test understanding of basic ideas and critical distinctions

    meant to be simple and straightforward, not complicated, if you understand

    not meant to be tricky or rely on obscure facts
  - think about plausibility and where I'm likely coming from
  - if it still seems ambiguous, say "I'm assuming this..." and carry on