Wireless systems

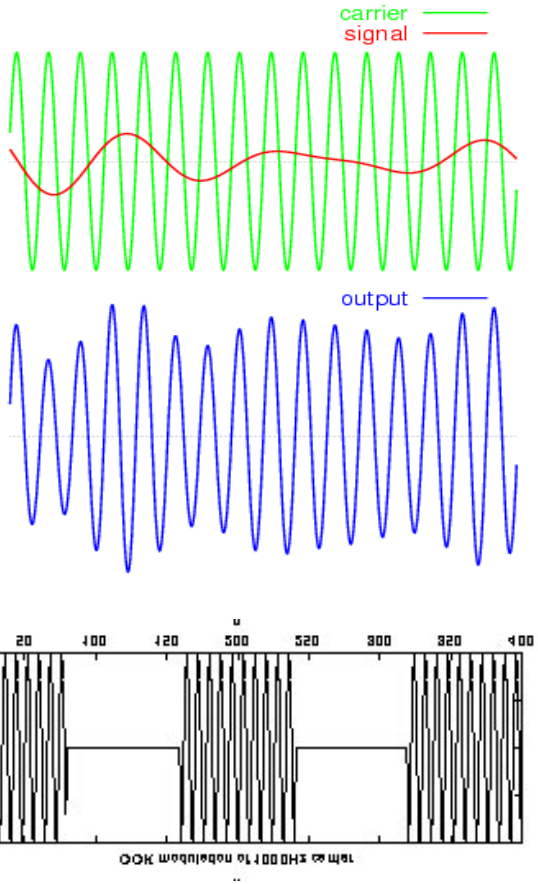
- includes issues of
  - hardware
    processors, storage, peripherals, networks, ...
    representation of information, analog vs. digital, bits & bytes
  - software
    applications, operating system
    organization of information, file systems, ...
    algorithms: searching, sorting, compression
  - communications,
    Internet, Web, TCP/IP, protocols
    bandwidth, speed, caching
    compression, error detection and correction
  - security and privacy; cryptography
  - intellectual property and ownership
  - social & legal & policy concerns

Wireless systems (2)

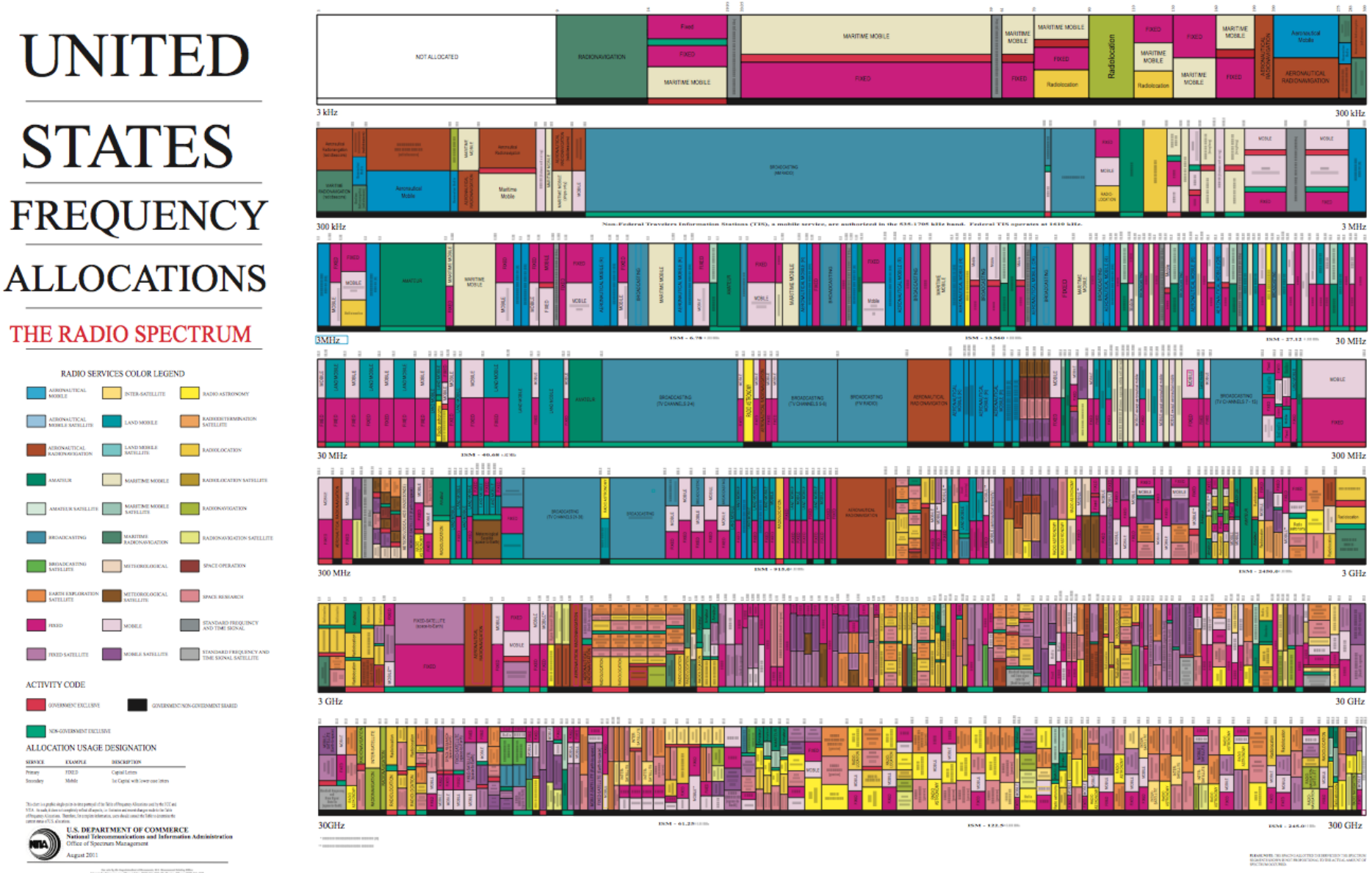
- how radio works
- radio spectrum allocation
- examples
  - cell phones
  - 802.11 (WiFi)
  - Bluetooth
  - GPS
  - RFID: prox, E-ZPass, store tags, passports, ...
  - ...
- tradeoffs
  - spectrum, power, range, size, weight, mobility
- non-technical issues
  - regulation, competition, ...

Radio

- electromagnetic radiation to carry information
  - without wires => "wireless"
- radiation is a wave of a particular frequency (in Hz)
- transmitter "modulates" the wave to impose information on it
  - amplitude (AM): change the power level
  - frequency (FM): change the frequency around a central value
  - digital: on/off
  - …
- receiver demodulates to recover the information
  - received signal strength varies directly with power level, and decreases with square of distance ("inverse square")
  - higher frequencies (shorter wavelengths) go shorter distances, penetrate obstacles less well



RF spectrum


UNITED
STATES
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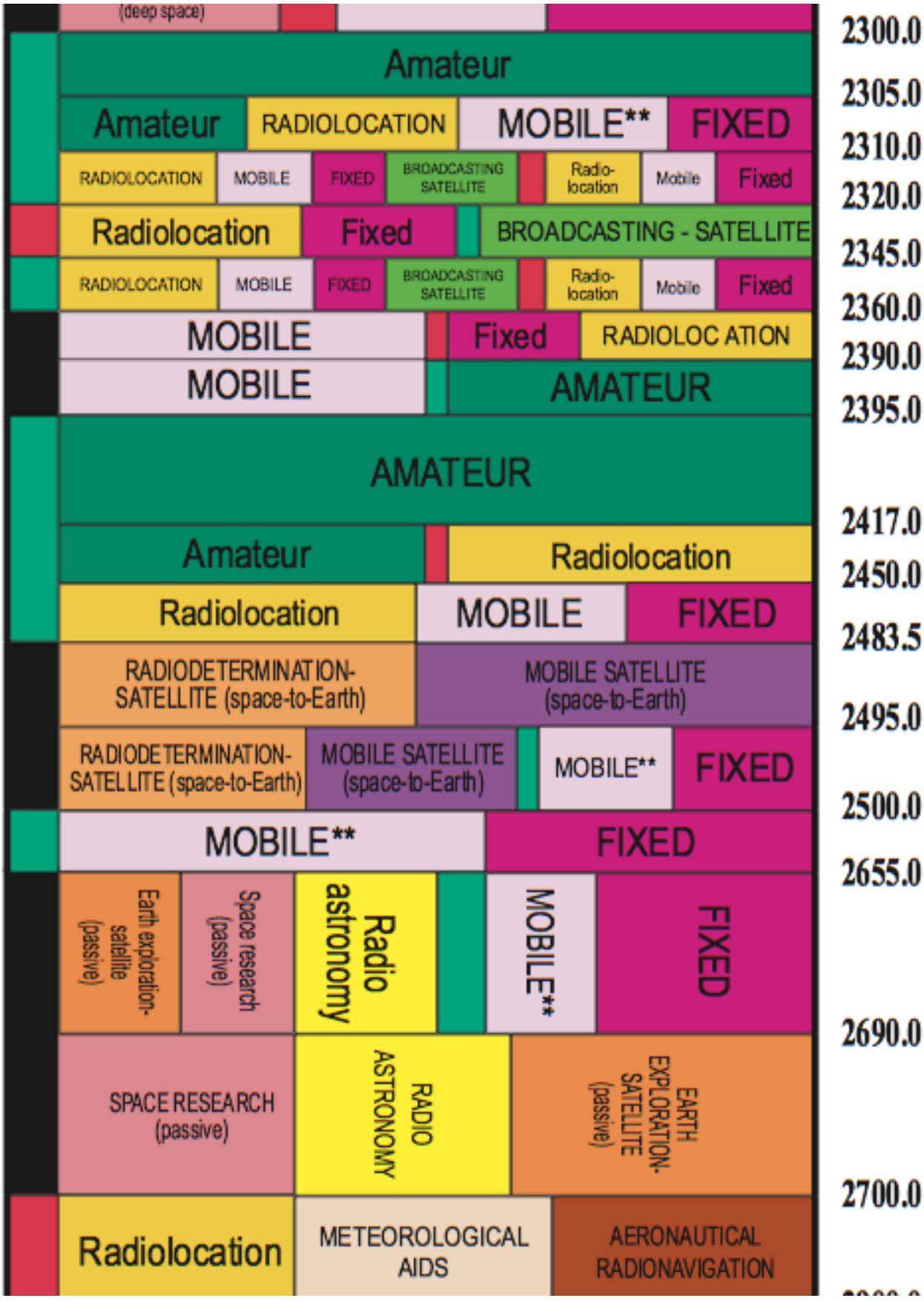
ALLOCATIONS
THE RADIO SPECTRUM
RADIO SERVICES COLOR LEGEND
ACTIVITY CODE
ALLOCATION USAGE DESIGNATION
U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management
August 2011
3 kHz
300 kHz
3 MHz
30 MHz
300 MHz
3 GHz
30 GHz
300 GHz



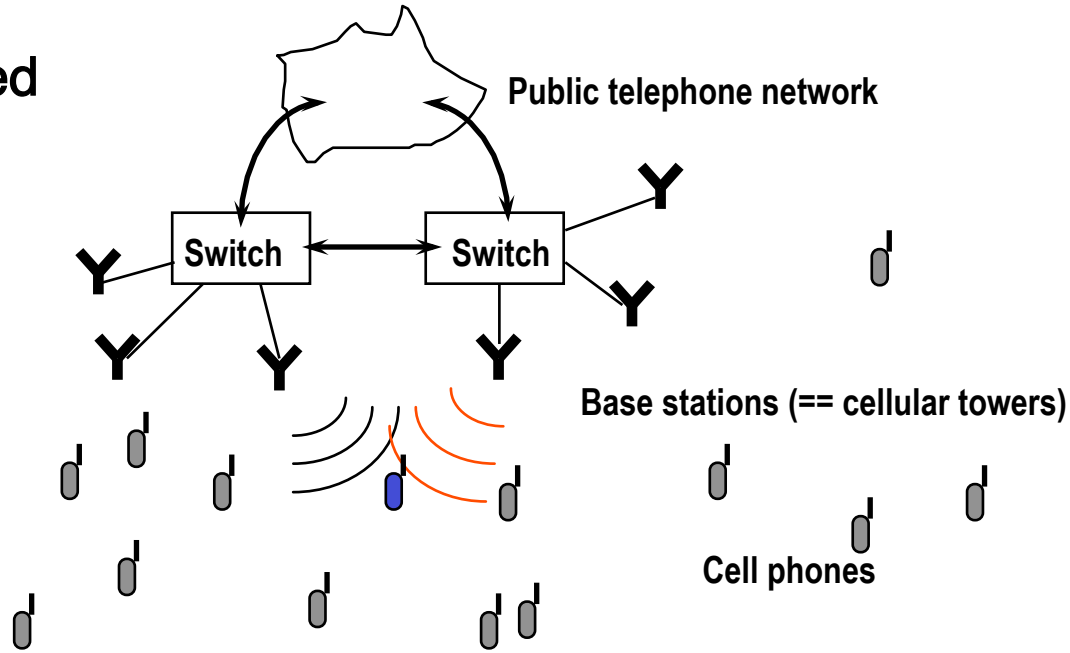
ISM – 2450.0±50 MHz

Cell phones 101

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

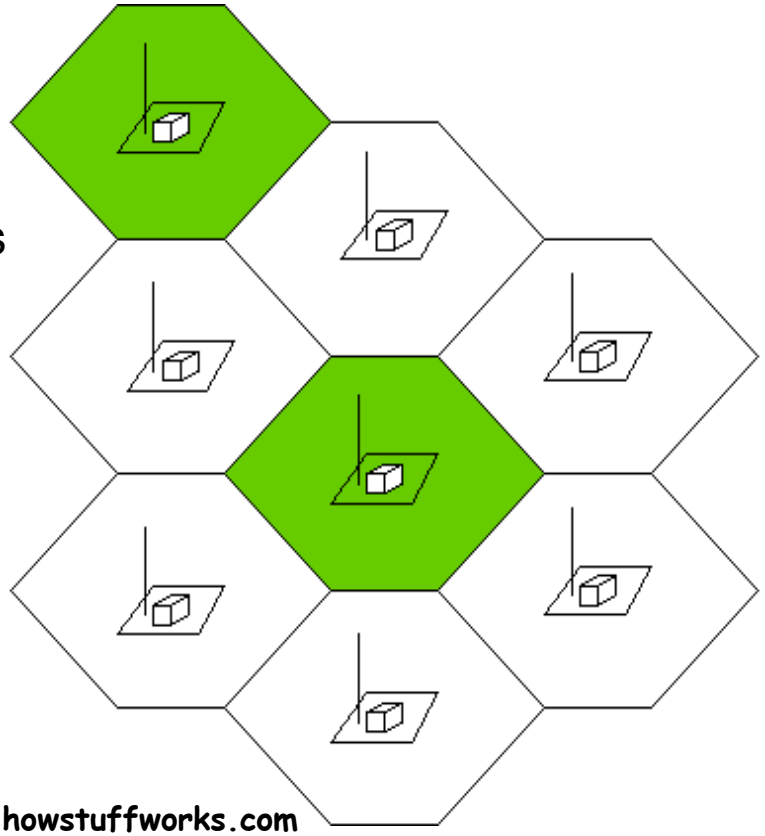
- moves long distances, at high speed, appears out of nowhere
- shares a very limited radio frequency spectrum with others
- operates with low power because it uses batteries

- this makes life complicated



Cells (a very idealized picture)

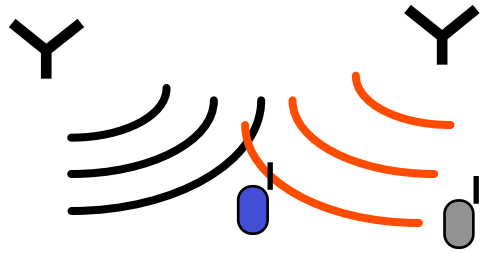
- divide geographical area into cells (notionally hexagonal)
- each cell has an antenna, handles all cell phones in its area
- available radio spectrum is divided into channels
  - two channels for one conversation, one for each direction
  - competing carriers operate on different frequencies
- each 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

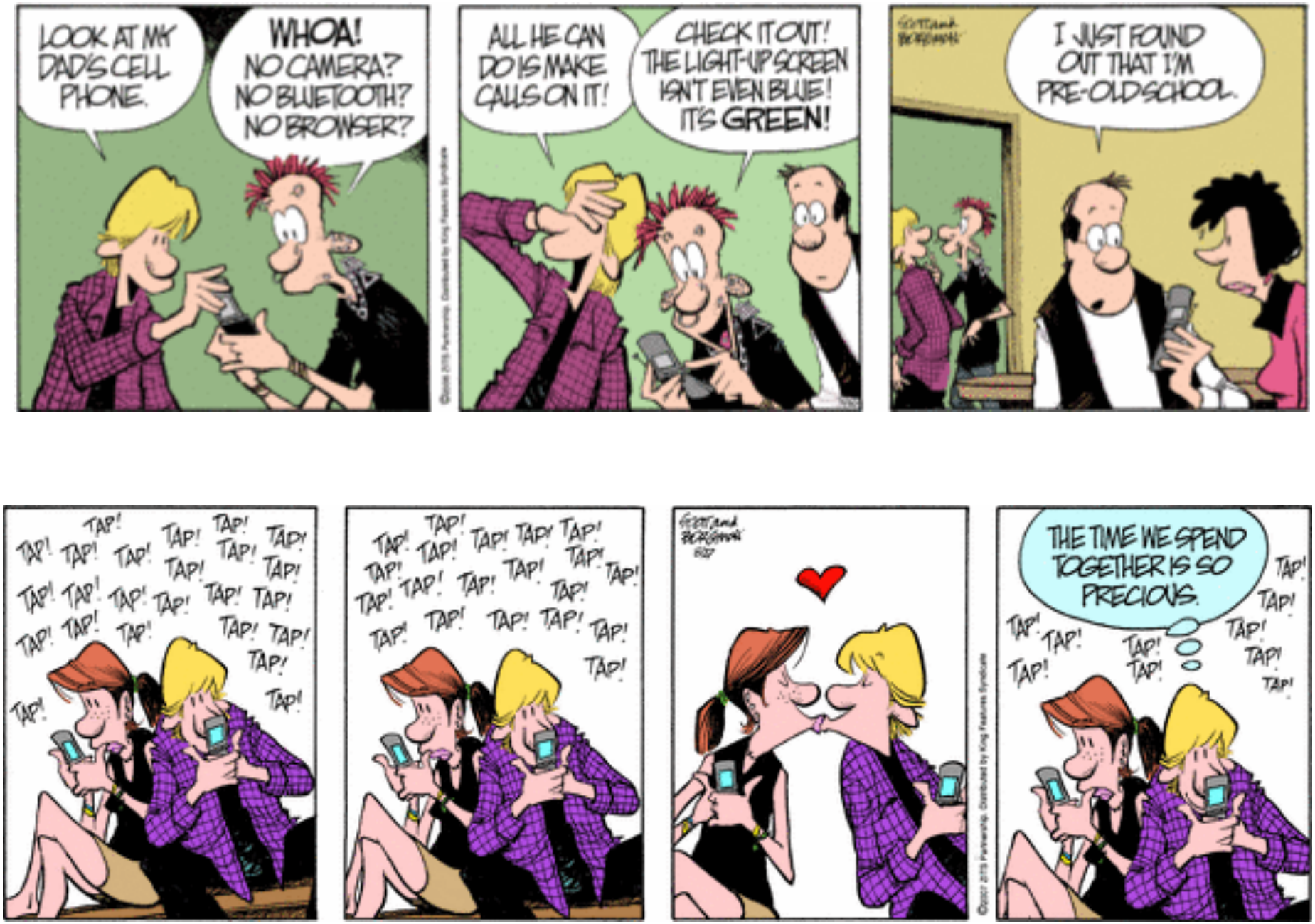
- should texting while driving be illegal (and enforced)?
  - how about just talking on a phone while driving? (Walking?)
- who determines where cell phone towers are permitted?
  - property rights versus eminent domain
- should cell phone jammers be legalized?
  - in theatres, trains, etc.
- should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

- location tracking and surveillance
  - FCC mandates that cell phones can be located 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 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


LOOK AT MY DAD'S CELL PHONE.
WHOA! NO CAMERA? NO BLUETOOTH? NO BROWSER?
ALL HE CAN DO IS MAKE CALLS ON IT!
CHECK IT OUT! THE LIGHT-UP SCREEN ISN'T EVEN BLUE! IT'S GREEN!
I JUST FOUND OUT THAT I'M PRE-OLD SCHOOL.
TAP!
THE TIME WE SPEND TOGETHER IS SO PRECIOUS.