CSE 291: Wireless and Communication in the Internet of Things

3g+ [wait, that's HSDPA]

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Today's Goals

- A 10,000 foot view of 3g and beyond
- Pros, cons, and pitfalls of using cellular networks for IoT deployments

Wait, isn't this a class on "low-power wireless"?

- Bad jokes in computer science:
  - *How do you make a supercomputer draw less power?*
  - *Turn it off.*

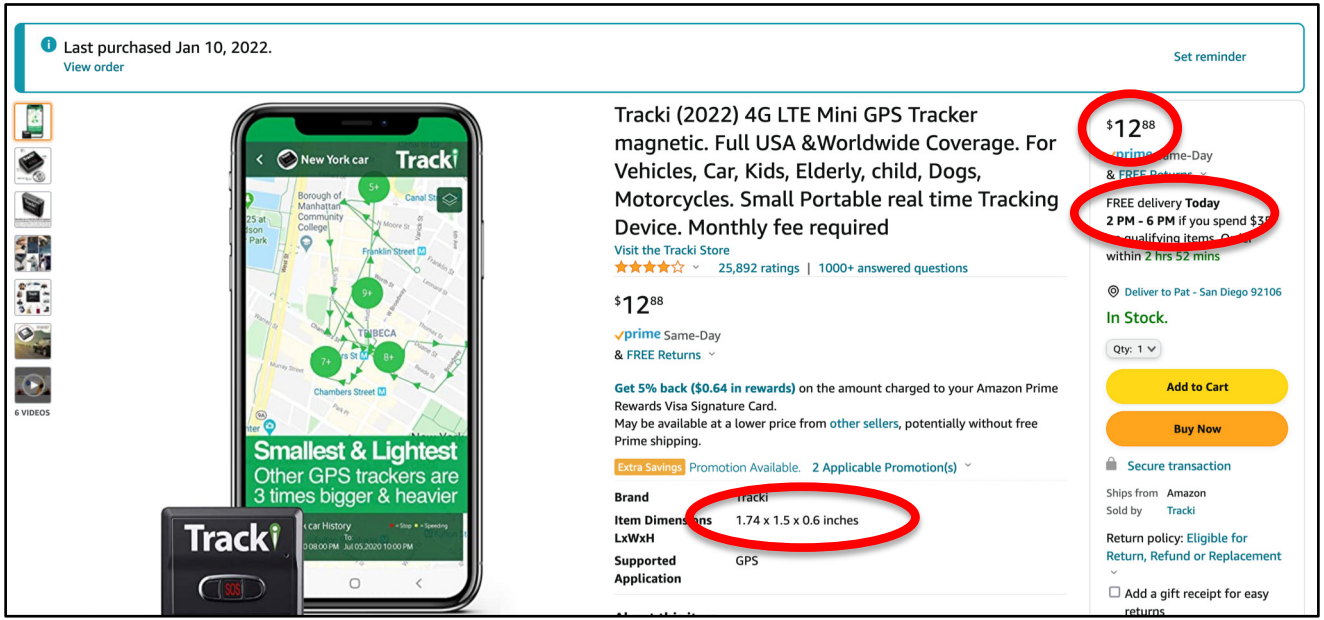
A purely hypothetical* motivating example

***aka what Pat did on Sunday this week**

- Research question: What happens to ”recycled” mobile phones?
- Research opportunity:
  - My partner is “trading in” her iPhone6 for an iPhone13 this week
  - Where does that phone go? What does T-Mobile do with it?
  - Any guesses?
- How might we answer this question?

These things aren’t creepy at all

- It’s actually sad and scary the wealth of ‘covert tracking’ tech



Limited battery life will save us!

- Not really…

> - Rechargeable battery life is up to 5 days (the more it moves the lesser the days) tracking real time every 1-5 minutes. If real time tracking is not needed, battery lasts 30-75 days tracking 1-3 times per day (using battery save mode). Optional accessory (not included ASIN B07YVNV82V) comes with 6 times longer life 3,500mAh battery + magnetic waterproof box, extends battery life to 2 weeks at 1 min update and up to 10 months tracking once a day

Limited GPS coverage will save us!

- Not really…

> - Works with GPS satellites when outdoors as primary tracking technology and when indoors Wi-Fi as a secondary backup tracking. Tracki listens to nearby Wi-Fi routers MAC ID, matching IDs to Wi-Fi database for accurate location when GPS is not available. See the tracking live on the map including compatible with Google Street view. Get real-time alerts when the tracker crosses a Geo-fence zone you set. Receive SOS, low battery, speeding, start moving alerts via App notification, SMS or email

Surely people will notice a big, bulky tracker right?

- I mean.. I'm hoping not

For a little bit of time, $$$ might save us

- Traditional cellular billing is fixed *per-unit* not *per-data*
  - Given what you've learned of cellular infrastructure, why might this be?
- But as we will see later, big effort to roll out IoT-aware infra

> • Unlimited distance real time tracking 4G LTE Monthly fee is required. Full USA & all countries worldwide coverage. International SIM card included. We are USA based company focused in GPS tracking. Our competition are just white label resellers. Our client is Vodafone a top cellular company. Track Vehicles, Cars, trucks, Children, dogs, elderly, motorcycle, ATV, boat, equipment, tools, assets, valuables. Monthly fee of 19.95USD is required or as low as 9.95USD (more details in the big paragraph)

Takeaway: Cellular provides the IoT the only reliable global coverage available today

- If the goal is deploy-today + work-anywhere, cell is the only option
  - (Or arguably satellite)
- That's not to say cell actually works everywhere!
  - Just the best-available
- **Contrast:** What is the insight behind AirTags?
  - Or Tile, Cube, etc.?

Outline

- Why do IoT developers care about cell?
- 3G/4G/Beyond
- What is cellular like for IoT?
  - MVNOs: The good and the bad

Starting with the end: the 3G sunset

- [As of Oct, 2021] announced retirements:
  - Verizon: Dec 2022
  - AT&T: Feb 2022
  - T-Mobile:
    - For Sprint customers / bands: Jan 2022
      - T-Mobile delays shutdown of Sprint 3G Network [now Mar 2022]
      - Anecdata: The phone that started this presentation was a Sprint phone that needed to be replaced; went to T-Mobile in mid-Oct; got new phone on Dec 30 #ChipShortagesAreHardYo
    - For original T-Mobile: July 2022
    - When do you think T-Mobile's 2G sunset is scheduled for?
      - Currently Dec 2022, and I'll believe that when I see it
      - n.b. Verizon and AT&T actually did sunset 2G

Why does 2G have staying power that 3G doesn't?

- T-Mobile's letter to Congress on 2g/3g sunset
  - n.b. Senator Schatz seems to get this stuff

6. How will the 2G and 3G shutdown impact non-cellular devices and other devices and systems that are not mobile phones on your networks? How many of these devices will be impacted in each state?

Non-cellular, data-only devices that rely on 3G data will need to be capable of LTE operation or will need to be upgraded. Devices that rely on 2G data will remain operational until that network sunsets at a later date, but such devices should still be upgraded in the long term.[6] For this response, we interpreted "non-cellular device" to mean any device that is not a feature phone or a smartphone. Non-cellular 2G/GSM and 3G/UMTS active devices accounted for less than 1% of traffic on the T-Mobile network as of the week of April 11, 2021.

[6] Note that all non-cellular 3G/UMTS devices also have 2G/GSM capabilities.

So what did [*]G provide over 2G anyway?

- Biggest thing is throughput
- And a spectrum land-grab
  - Wireless providers advocated [successfully] for [global] release of additional spectrum to support new, faster wireless
  - Lots of [initial] 4G rollout also on new spectrum
    - But no more coming — sunsets only way to get more 4G spectrum
  - 5G is [mostly] on much higher bands, not suited for 4G

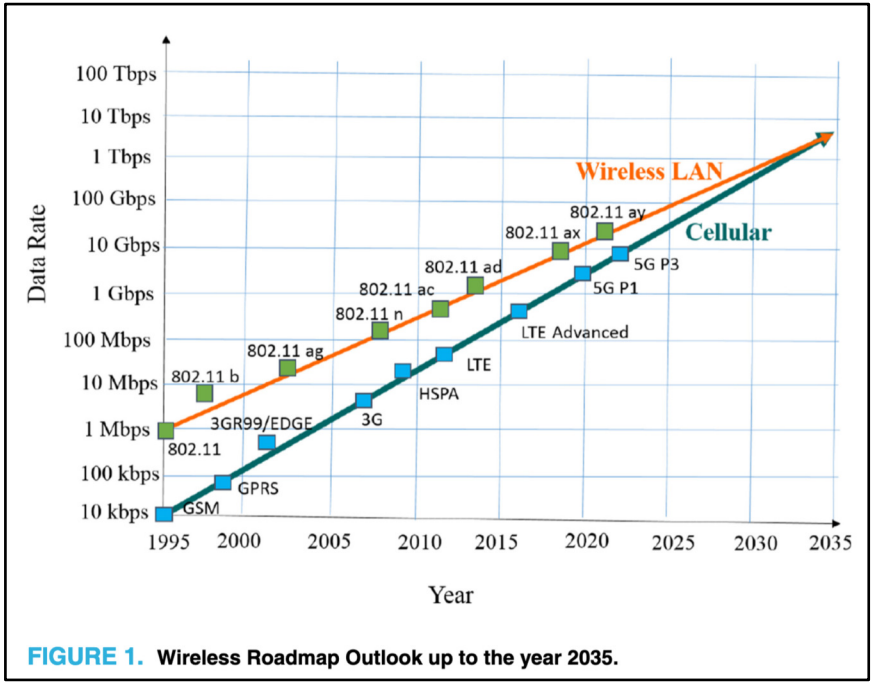


FIGURE 1. Wireless Roadmap Outlook up to the year 2035.

Terahertz Band: The Last Piece of RF Spectrum Puzzle for Communication Systems (preprint; Elayan et al.)

Aside: Eventually, the naming thing got annoying, so an international standards body fixed* it

*Yeah, you know how this story will end

- The International Telecommunications Union (ITU) is a UN branch
  - ITU-R set standards for what can be considered "a 4G technology"
- "Generations" are now defined by speed
  - E.g. to qualify as "a 4G technology": 100 Mb/s+ (mobile), 1 Gb/s+ (stationary)
  - Fun game: How fast is LTE?
    - LTE spec maxes out at 300 MB/s down and 75 MB/s up
    - It seems LTE has been retroactively classified as 3.95G
      - [By everyone except the wireless carriers?]

Corollary to improved throughput is improved energy performance

- Same philosophy as high-performance architecture, etc
  - There is always baseline load, which going faster amortizes

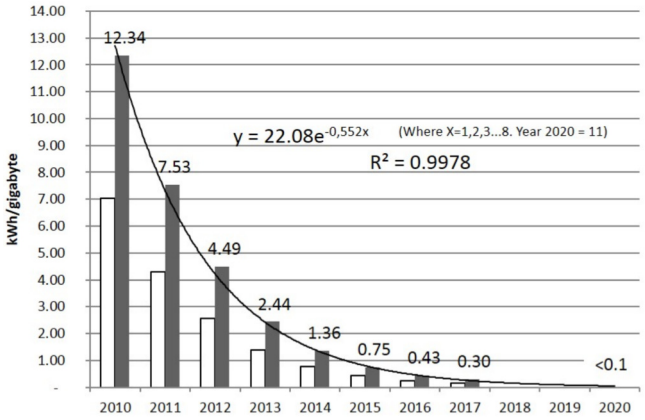


Figure 3. Development of energy efficiency of transmitted mobile data (kWh/gigabyte) in Finland during 2010–2017. Grey bars represent estimated consumption for production networks and white bars for base stations only. Exponential trends (y = y(x)) until 2020 were estimated by means of least squares fit using the data in the grey histogram. X in these equations refers to numbers 1 to 8; and 11 corresponding to years from 2010 through to 2017; and 2020.


sustainability
MDPI
Article
Evaluating the Energy Consumption of Mobile Data Transfer—From Technology Development to Consumer Behaviour and Life Cycle Thinking
Hanna Pihkola *, Mikko Hongisto, Olli Apilo and Mika Lasanen

But energy per transaction is complex

- Radios, cellular protocols, and cellular providers have state machines
  - Hard to predict *a priori* and globally ☹

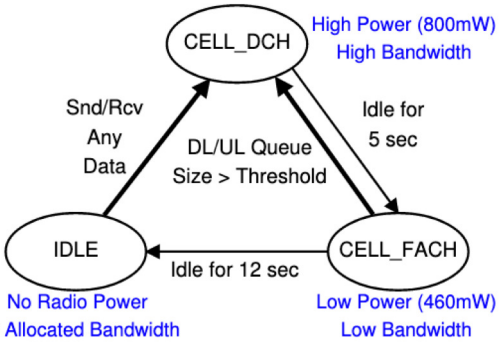


Figure 2: The RRC state machine for the 3G UMTS network of Carrier 1

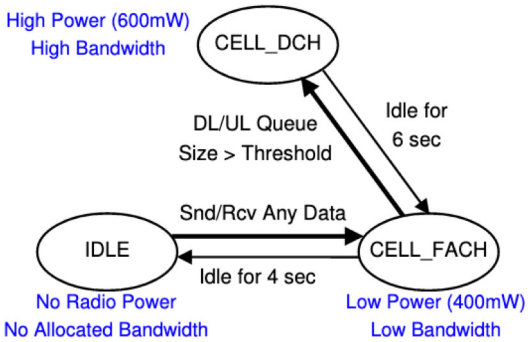


Figure 3: The RRC state machine for the 3G UMTS network of Carrier 2

Characterizing radio resource allocation for 3G networks; Feng Qian, Zhaoguang Wang, Alexandre Gerber, Zhuoqing Morley Mao, Subhabrata Sen, Oliver Spatscheck; SIGCOMM'10

Numbers from one implementation

- Take these as a reference point [from 2013!], not gospel

TABLE 2: Saving power with the DVFS.

CPU access to memory	DVFS and CSW are disabled	CSW is enabled	Saving power	DVFS is enabled	Saving power
2G CPU	280 mW	265 mW	5.3%	221 mW	21.1%
3G CPU	198 mW	176 mW	11.1%	157 mW	20.7%
LTE CPU	183 mW	168 mW	8.2%	141 mW	23%

The System Power Control Unit Based on the On-Chip Wireless Communication System

So what is 5G doing differently?

- Largely, 5G is a small(er)-cell technology
  - "Urban optimized"
  - Unlikely to roll out to all geographic area (because of infrastructure cost)
- This does also allow for higher performance

What matters is the trendline

Outline

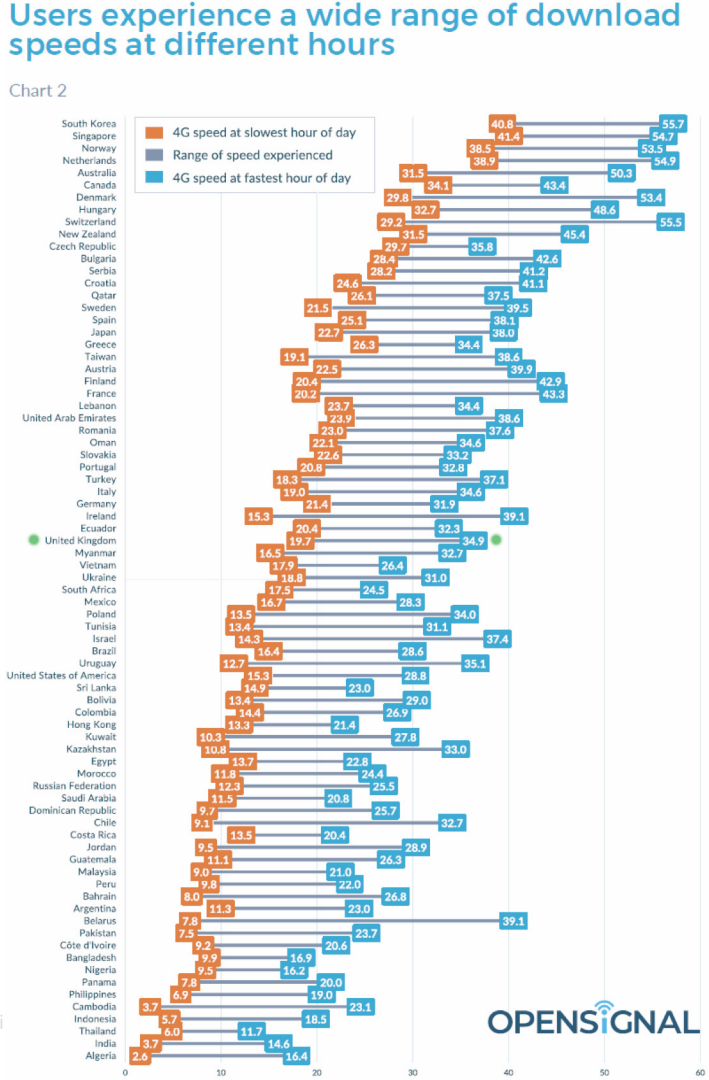
- Why do IoT developers care about cell?
- 3G/4G/Beyond
- What is cellular like for IoT?
  - MVNOs: The good and the bad

#1: It's expensive

- More on this in this week's assignment…

Sizing networks is hard

- Sometimes you just lose performance…



Traffic fluctuates in all networks, for cellular it becomes a function of both when and where you are

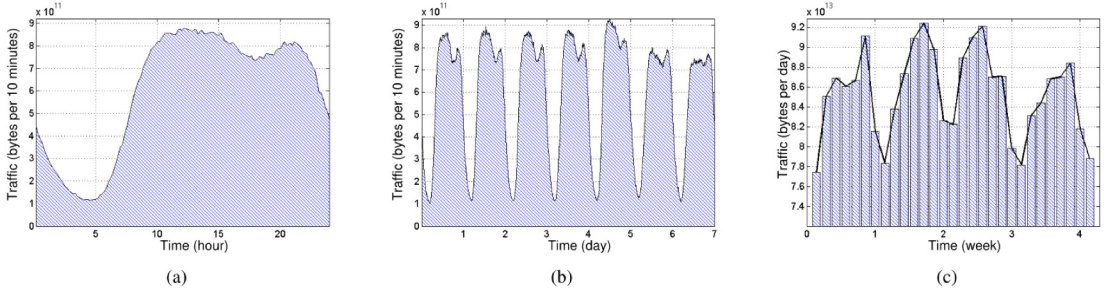


Fig. 1. The temporal distribution of cellular traffic at different time scales. (a) Hourly. (b) Daily. (c) Weekly.

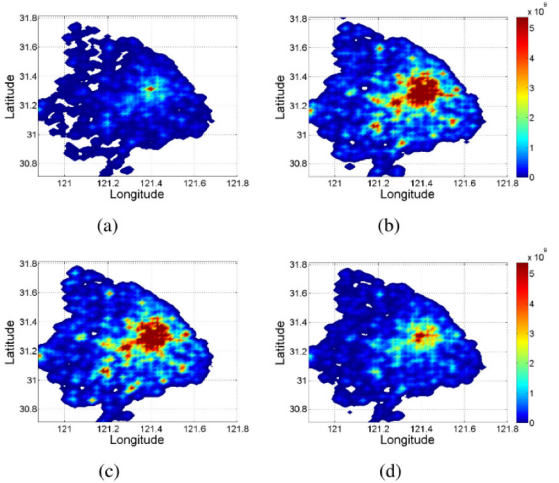
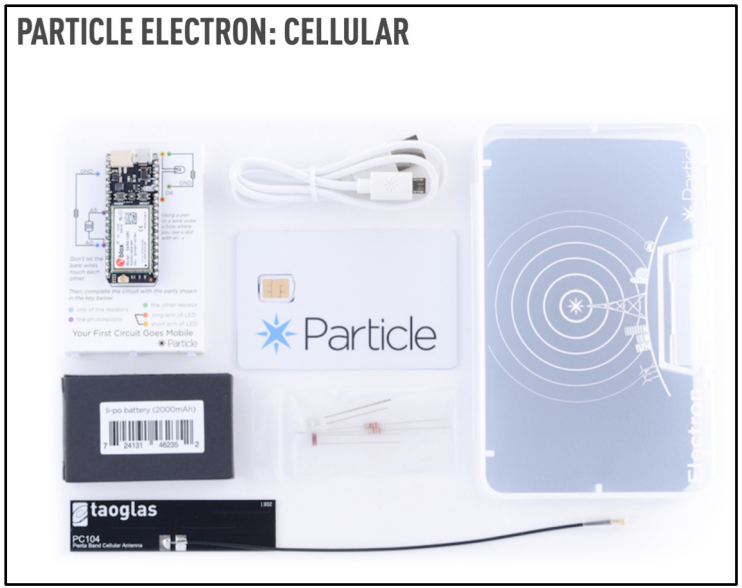


Fig. 2. The spatial distribution of cellular traffic at different time. (a) 4AM. (b) 10AM. (c) 4PM. (d) 10PM.

Understanding Mobile Traffic Patterns of Large Scale Cellular Towers in Urban Environment; Xu, Li, Wang, Zhang, Jin; IEEE ToN

Why does this matter for IoT Deployments?

- Say you're building a power grid sensor you want to deploy globally…



The Electron is a tiny development kit for creating 3G cellular-connected electronics projects and products. It comes with a Particle SIM card with service in more than 100 countries worldwide.

Device Cloud

Access to the Device Cloud includes: 3MB of cellular data per device/mo (additional data $0.40/MB for most countries) First 3 months of Device Cloud FREE ($2.99 per device/mo after) Device Cloud Features:

- Device Management
- Over the Air Firmware Updates
- Fully Managed Connectivity
- Developer Tools
- Integrations

What is a MVNO
"Mobile Virtual Network Operator"

- Decoupling the builders of infrastructure from the sellers
- Not a new concept, but seeing aggressive growth
  - MetroPCS; Cricket; Boost Mobile; etc
  - GoogleFi; Xfinity Cellular

So how does Particle, a small IoT platform startup, provide global cellular coverage?

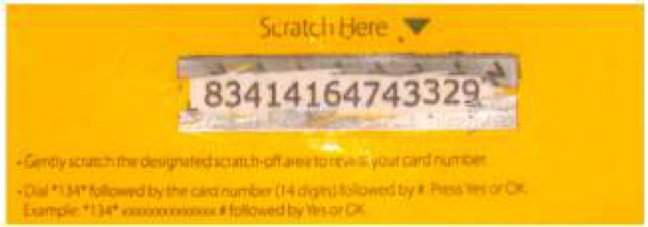
- We deployed some Electrons in Accra, Ghana sending a message once per minute 24/7 for a few weeks
  - PRR [POST Reception Rate]?
    - 1: 10% 2: 20% 3: 30% 4: 40% 5: 50% 6: 60% 7: 70% 8: 80% 9: 90%
  - Almost zero PRR from ~7-9am and ~4-7pm daily
- Introducing traffic priority
  - Call Particle: "What gives?"
    - Particle buys from T-Mobile
    - T-Mobile buys from Deutsche-Telekom [didn't own them yet]
    - DT buys from Vodafone
    - Vodafone buys from MTN
    - MTN has 5 tiers of traffic priority on their network [guess which tier we were in?]

So how do you get higher on the priority list?

- You buy from MTN
- … also not easy
  - Limit of 3 SIMs / person due to fraud
    - Particularly important due to prevalence of SIM-based mobile money

So how do you deploy in Tanzania?

- Not limited in SIMs, but limited in *payment plans*
- Post-paid plans not an option
  - Need to purchase 'airtime recharges'
  - Which you use by texting from that phone to an SMS shortcode
    - So now you must have in-country staff!



So how do you actually realize this claim?

- Good. Question.

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  - (Or arguably satellite)
- That's not to say cell actually works everywhere!
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- **Contrast:** What is the insight behind AirTags?
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On your own: Understanding global cellular

- No synchronous lab on Friday this week
- Instead: Research assignment
  - What does cellular look like around the world?