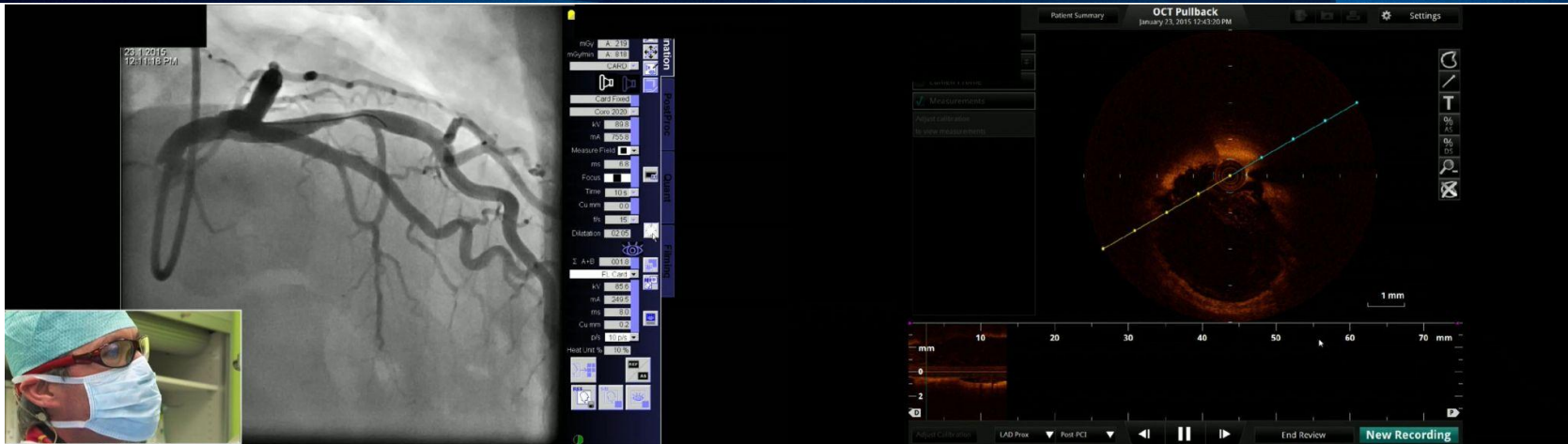# cesnet

5G Networks: Are we there yet?

Miloš Liška
Sitola, Telč 14.9.2023

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- **Why anything special?**
  - We do have Zoom, Pexip, EduMeet, MS Teams, Webex, Meetup etc.
- **What if you need high-quality video**
  - Full HD at least like in TV but also 4K, 8K (or 16K) video
  - Stereoscopic video, 360° video
- **More video inputs at once**

- **Low-latency**
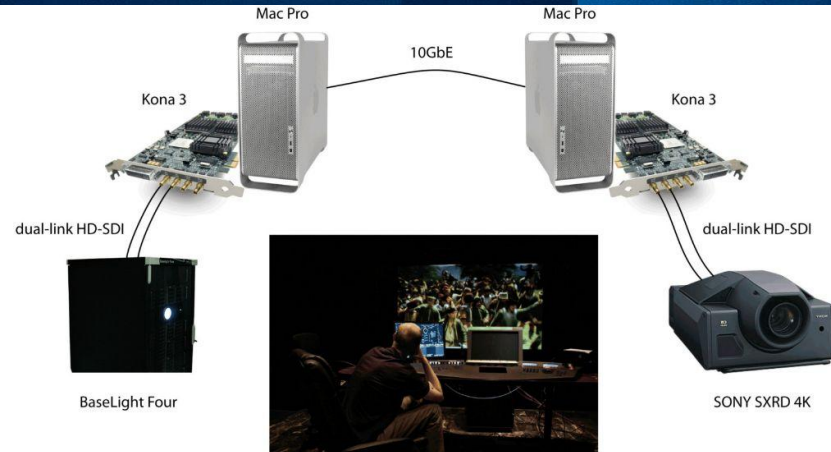 - as low as tens of ms end-to-end up to ~170ms end-to-end w/ processing

Mac Pro

Mac Pro

10GbE

Kona 3

Kona 3

dual-link HD-SDI

dual-link HD-SDI

BaseLight Four

SONY SXRD 4K

UltraGrid

glif

- We develop state-of-art SW for very high-quality and low latency audiovisual transmissions
- UltraGrid

  - A swiss-army-knife SW platform for very high-quality interactive video (up to 16K) and audio transmissions
  - As low latency as possible on commodity hardware and reasonable networks
  - Point-to-point and point-to-multipoint transmissions
  - Use of commodity (gaming) hardware, laptops, even Raspberry Pi
  - Linux and Windows PC and Mac OS platforms
  - Commodity video capture cards, gaming capture cards, webcams, Ximea cameras
  - Commodity sound cards, USB sound cards (ASIO not officially supported)
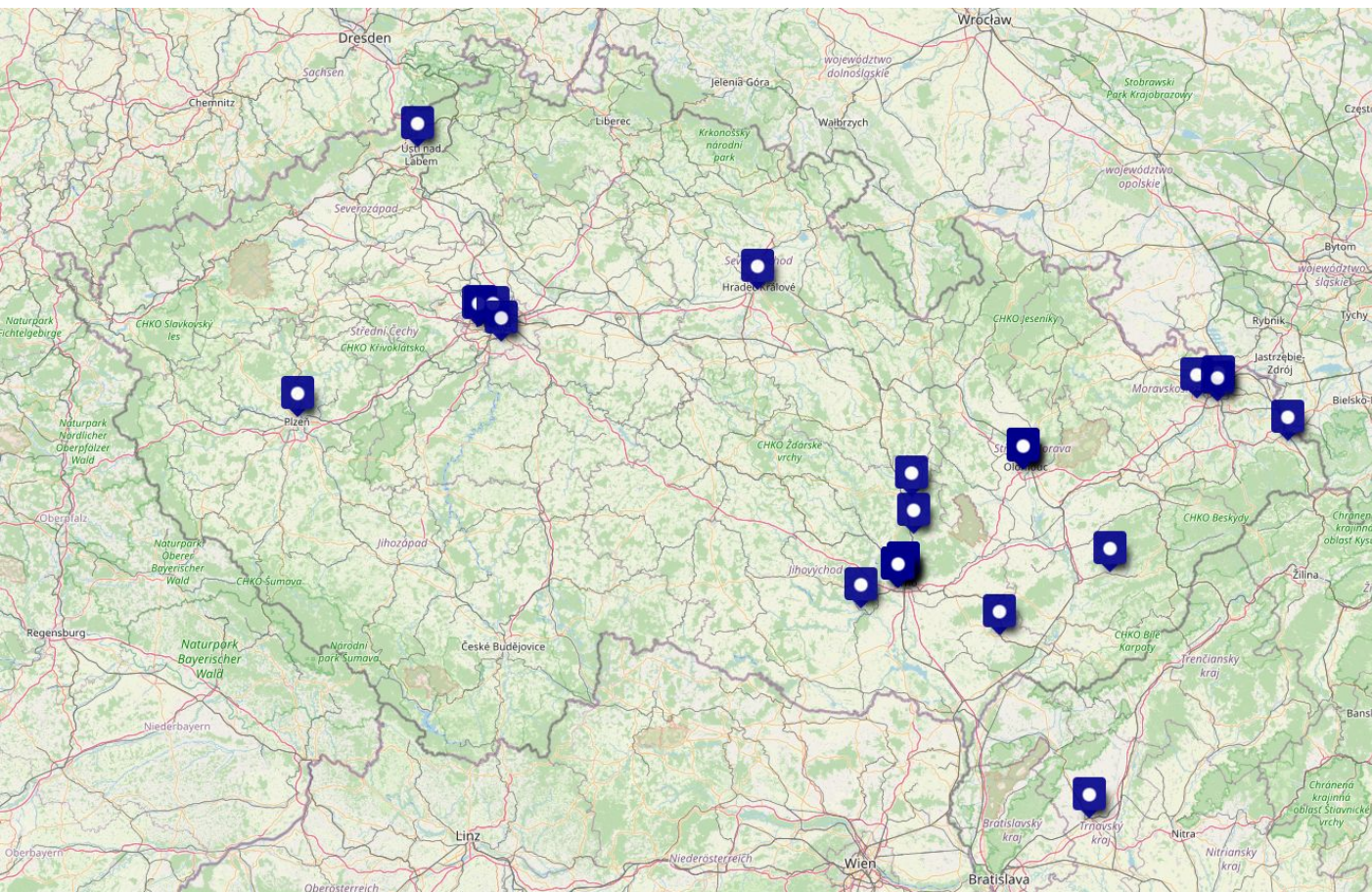 - Commodity GPU cards

- Video assisted surgeries

- Dental surgeries, Gastroenterology, Gynecology
- Stroke management simulations
- Cardiology
  - Interventional cardiology, Electrophysiology
- Ear-nose-throat surgeries
- General surgery
  - Non-intubated lungs surgery
- Urology
- Including 3D video assisted surgeries using the DaVinci robot
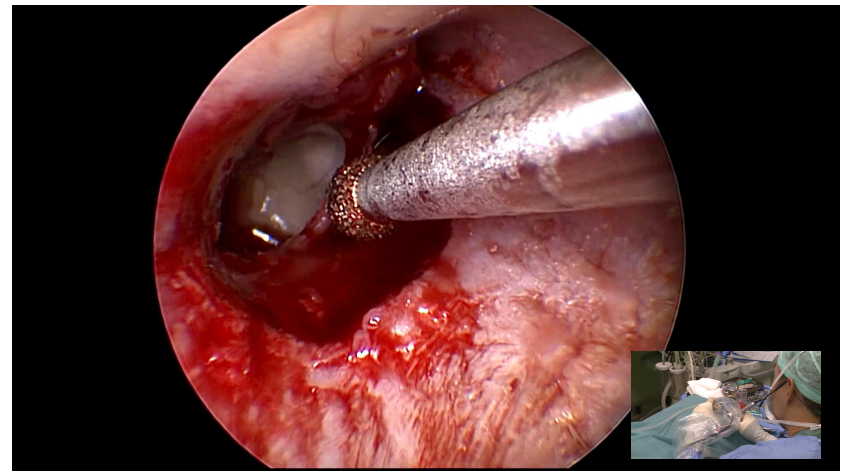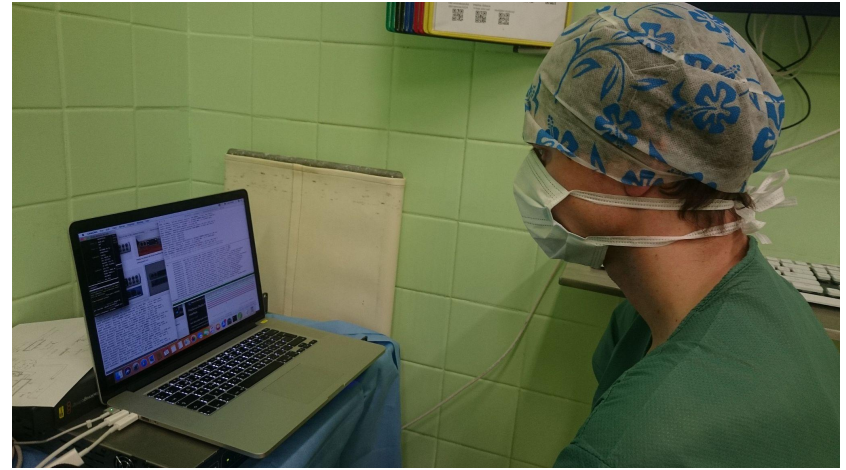
IKAK FNUSA Brno, FN HK , FN Brno, CKTCH Brno, Institute of Cardiology in Anin, Warsaw (Poland), IKEM, Nem. Třinec, FN Olomouc, Nemocnice Blansko, Boskovice, Ivančice, Kyjov, FN Královské Vinohrady, FN Plzeň, FN Trnava, Nem. Vítkovice Ostrava, Baťova nemocnice Zlín, FN HK, Masarykova nemocnice Ústí nad Labem, VFN Praha ARK FNUSA, Dentální klinika Praha Holešovice, Nemocnice Na Homolce, DMC Klinika Hradec Králové. IKEM, FN Ostrava, MNO Fifejdy, Masarykova nemocnice Ústí nad Labem, FN Motol

- Any "reasonable" network
- Beginning from DSL up to 100Gbps optical networks
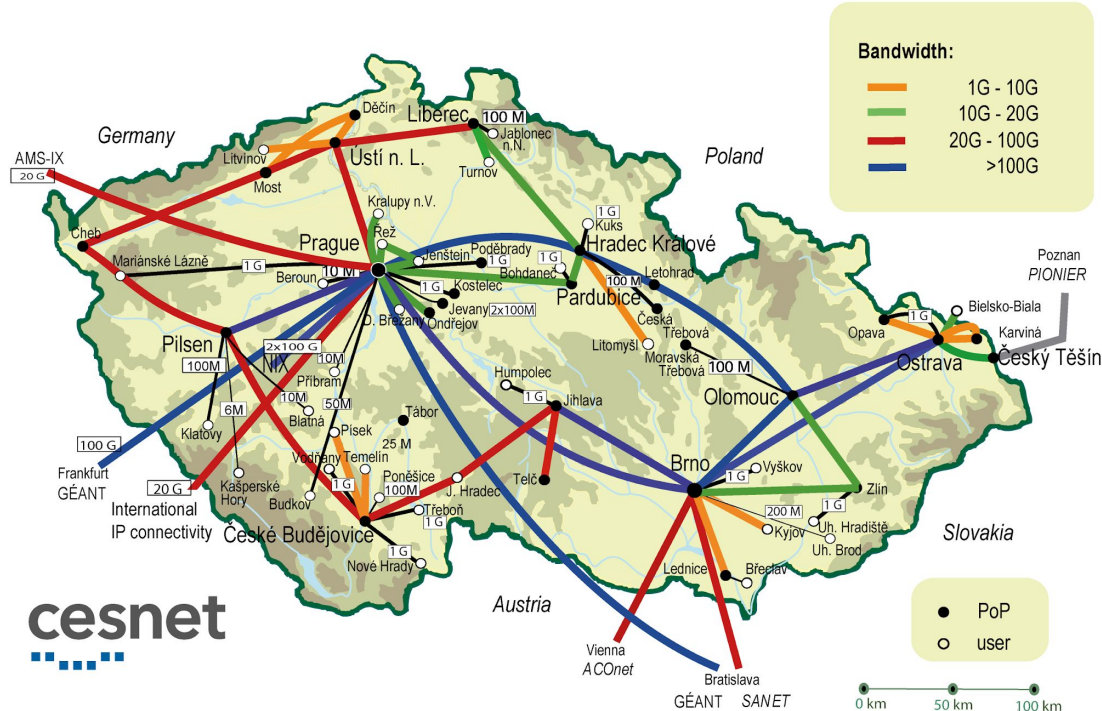
- We had been building network infrastructure avidly 20 years ago
  - Nothing was a problem
- We do have high-speed networks today, right? Right?
  - Aggregation
  - Networks are really best effort only
  - Packet loss is quite inevitable, it is necessary to use FEC techniques
- Poor IPv6 adoption (especially on last mile)
- NAT (w/ dynamic port reassignment)
- Firewalls and Security incl. Netflow analysis

- We can do high quality (and low latency) AV transmissions using VPNs (but it is a major PITA)

- 5G causes cancer, 5G is the cause for COVID-19, 5G weakens the immune system
- 5G kills birds or insects
- COVID-19 is a cover to embed microchips within COVID-19 vaccine for controlling people via 5G, The 5G grid is part of a larger surveillance and artificial intelligence agenda, 5G frequencies are used for crowd dispersal, 5G maps the insides of bodies and homes, 5G replicates inside the body and causes re-radiation
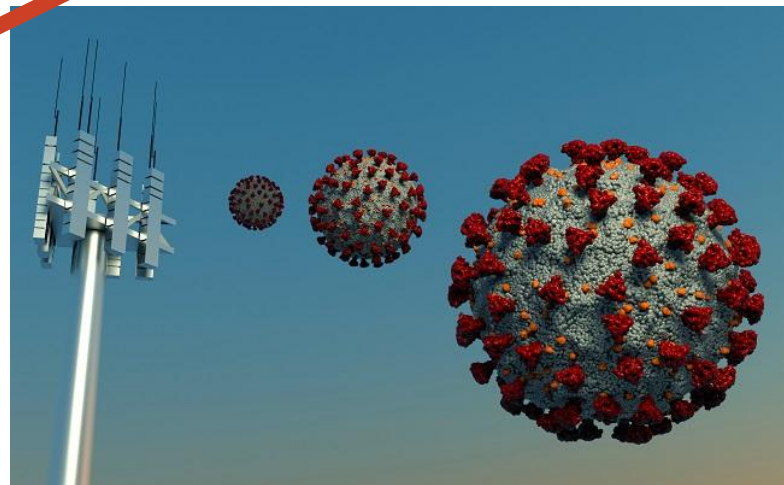
- **Cellular network**
- **5G New Radio**
  - Low-band - similar frequency range to 4G cellphones, 600–900 MHz, potentially offer higher download speeds than 4G: 5–250 Mbps, coverage similar to 4G
  - Mid-band - microwaves of 1.7–4.7 GHz, speeds of 100–900 Mbit/s
  - High-band - millimeter wave band 24–27 GHz, gigabit speeds, coverage up to 600m
- **Network Core**
  - Mobility management, routing, security, policy control, charging, and subscriber data management
  - Data network
  - Standards call for 100/50Mbps granted per connected client
  - Peek throughput of 10Gbps*

* Applies to a cell, when there is only one user on the network! Also mind the aggregation. 100Mbps download speed was already available with 4G. That's only 100 clients per cell!
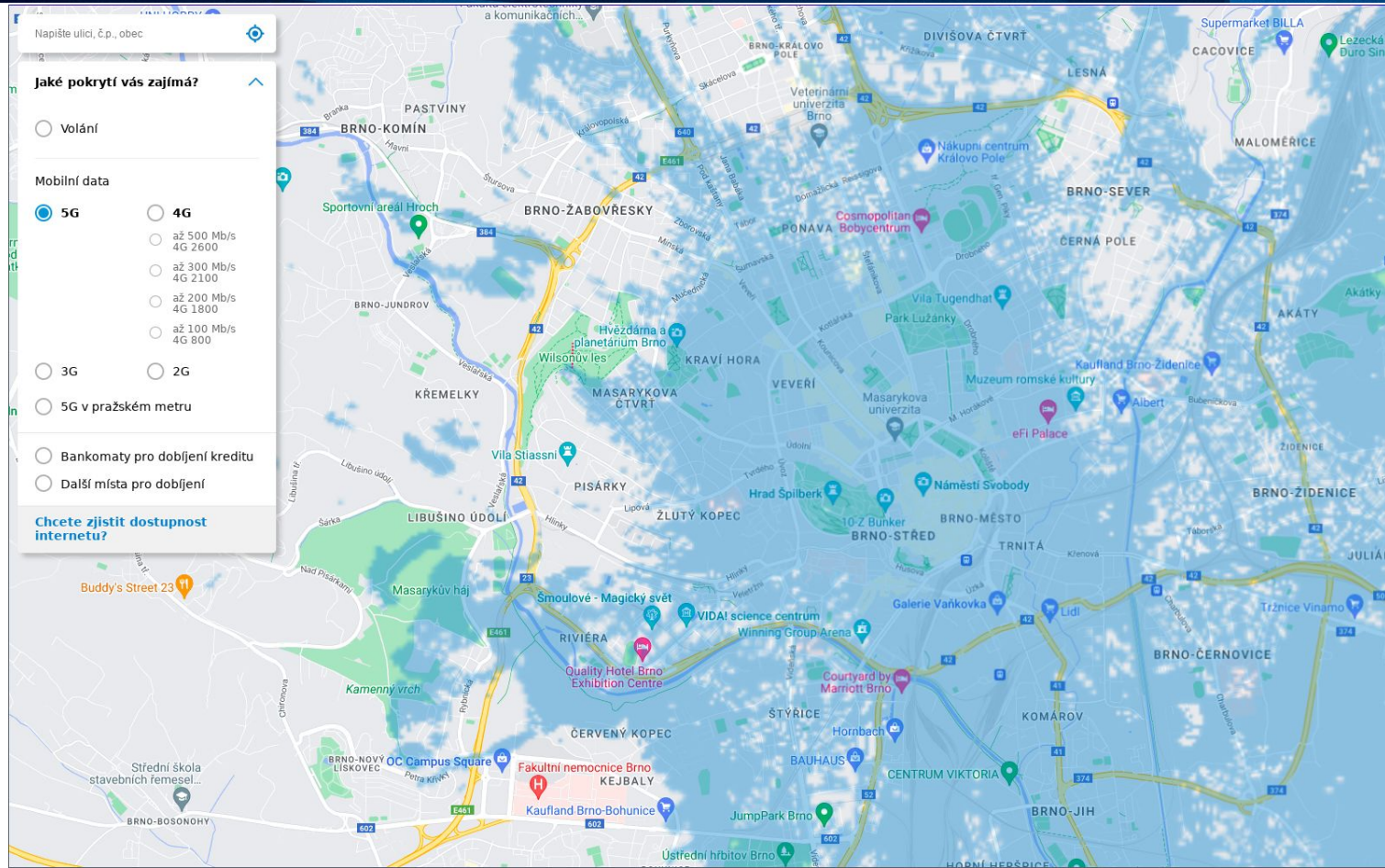
- Robustel GSM-R5020-5G-B 5G router, std. antennas
  - Decent industrial IoT 5G router
- Indoor, typical deployment in hospitals in our case

- IKK FN Brno   16,3Mbps D/10,0 Mbps U, LTE, RSRP -109dBm, RSRQ -15dBm
- IKAK FNUSA Brno   36,6Mbps D/35,2 Mbps U, LTE, RSRP -96dBm, RSRQ -8 dBm
  - But 1Mbps D/0,25Mbps U behind first automatic door
- Hotel Flora Olomouc   14,7Mbps D/23,4 Mbps U, 5G, RSRP -85dBm, RSRQ -14 dBm
  - 5G NSA (non standalone), LTE 10,3 Mbps U/19,5 Mbps D
- Cubex Praha   110,5Mbps D/35,5 Mbps U, LTE, RSRP -86dBm, RSRQ -10 dBm

RSRP (dBm) - (Reference Signal Receive Power) - signal intensity, **RSRQ** (dB) - (reference signal quality)

FAIL

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2G 3G 4G 4G+ 5G

200 679 collected data since 08/03/2021 in displayed area.
Last update : 08/22/2023 08:06 UTC
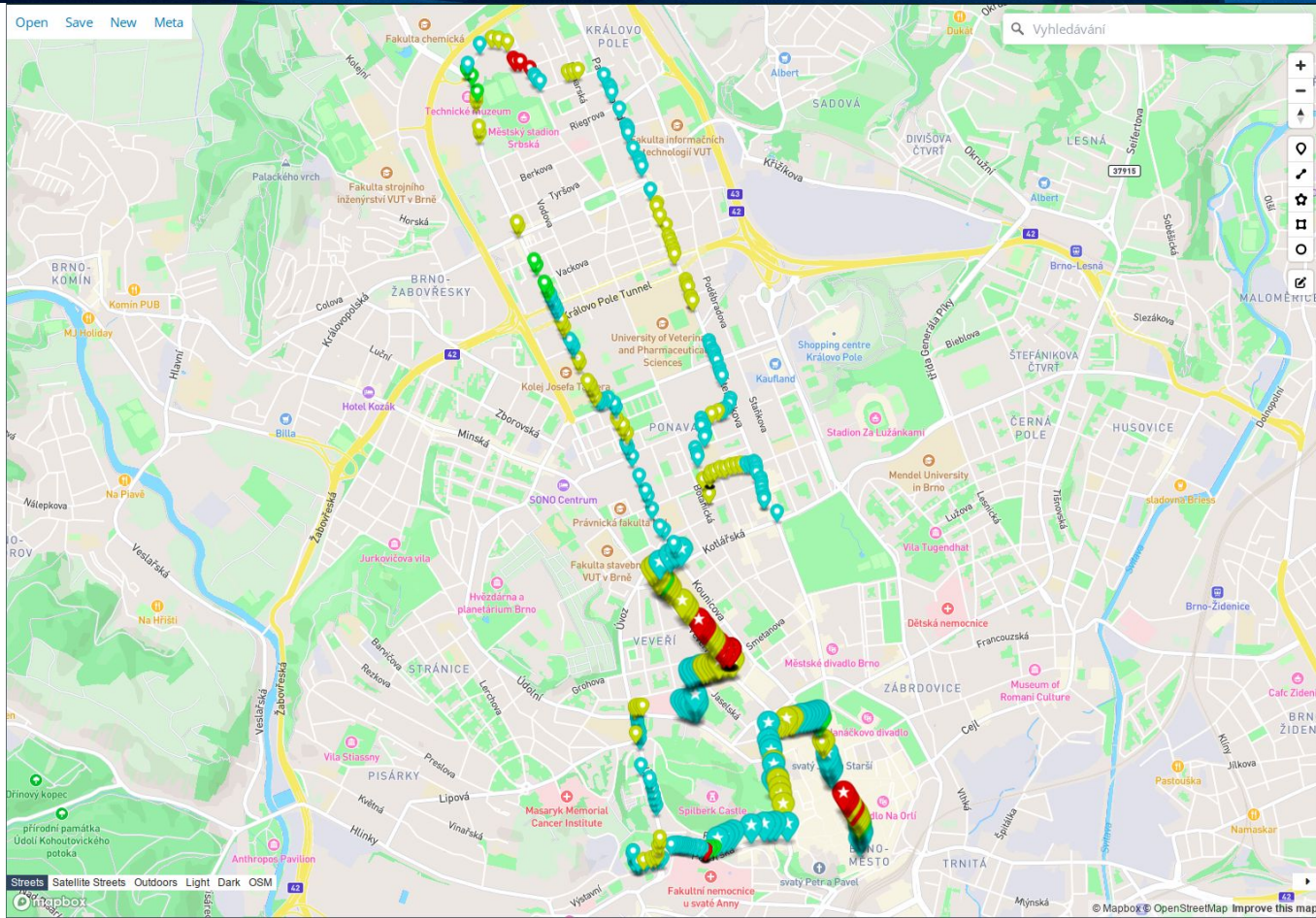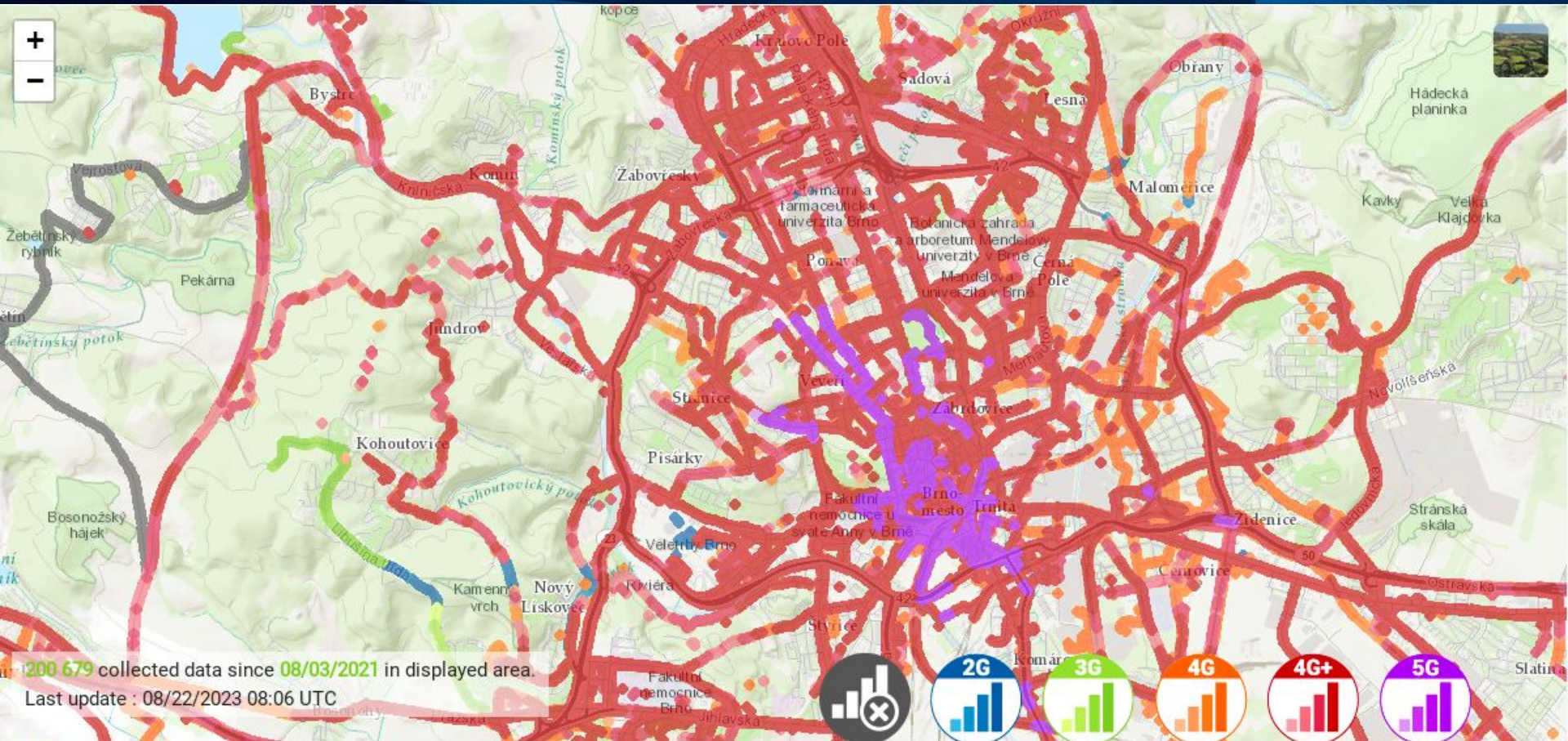
- Real 5G radio coverage is much smaller than advertised
- Non standalone architecture - 4G Core only - limited to ~150/50Mbps by design
- Indoor usage vs. outdoor usage
  - Outdoor usage basically corresponds to what is advertised
  - Indoor usage – generally **FAIL**
  - Sitola is a nice exception – 4G LTE only, but full throttle, close to BTS w/ direct visibility
- NAT
  - Dynamic port reassignment
- Somewhat usable for HD/4K streaming/broadcasting but hardly for low-latency and high-quality video transmissions

- 2019 Roland Garros French TV, Orange, VLC authors experiment
- 2x 100Mbps HEVC10 8K60p unicast (TV)
  1x 100Mbps HEVC10 8K60p (Orange)
- **2 5G** 3.6GHz **cells** w/ 5G core, 250Mbps
  each covering a single tribune!
- Also a huge latency just below 10s
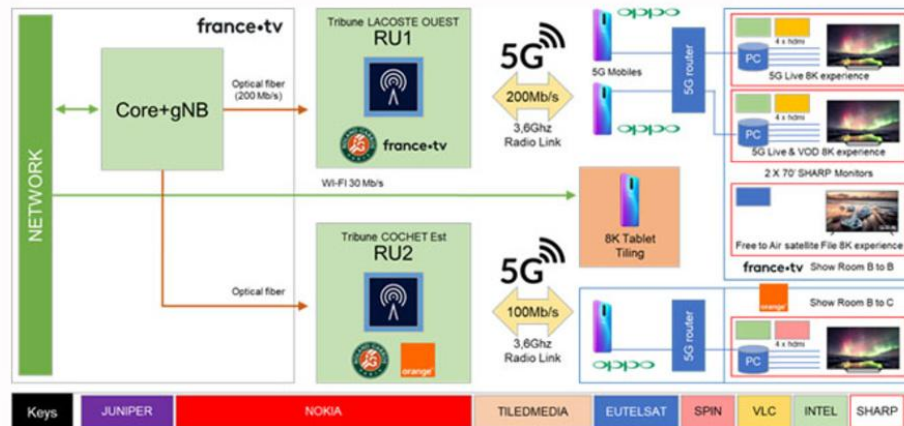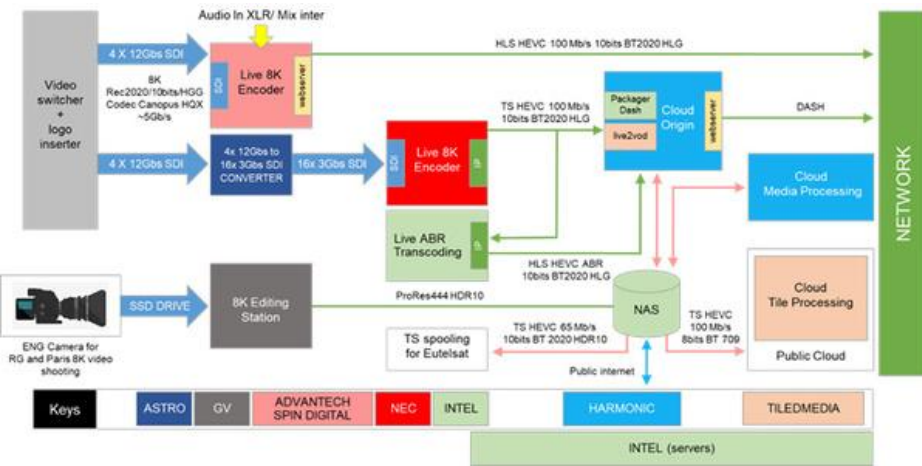
- Sitola, Fri 25 Aug 2023, 12:45
- 4G LTE, Band 3 1800MHz, RSRP -68dBm, RSRQ -7dBm
- 192,4Mbps D/64,5 Mbps U

- hd13 → 4G LTE → coral.fi.muni.cz
- 4K30p, H.264/HEVC, ABR 50Mbps, UDP
- Rate limiting!
- **No packet loss!** 😮
- End-to-end latency ~170ms

- 26,5 – 27,5GHz band (mmWave)
- CTO (Czech Telecommunications Office) eventually decided to divide the band to 200MHz subbands, theoretical throughput still 2,5Gbps
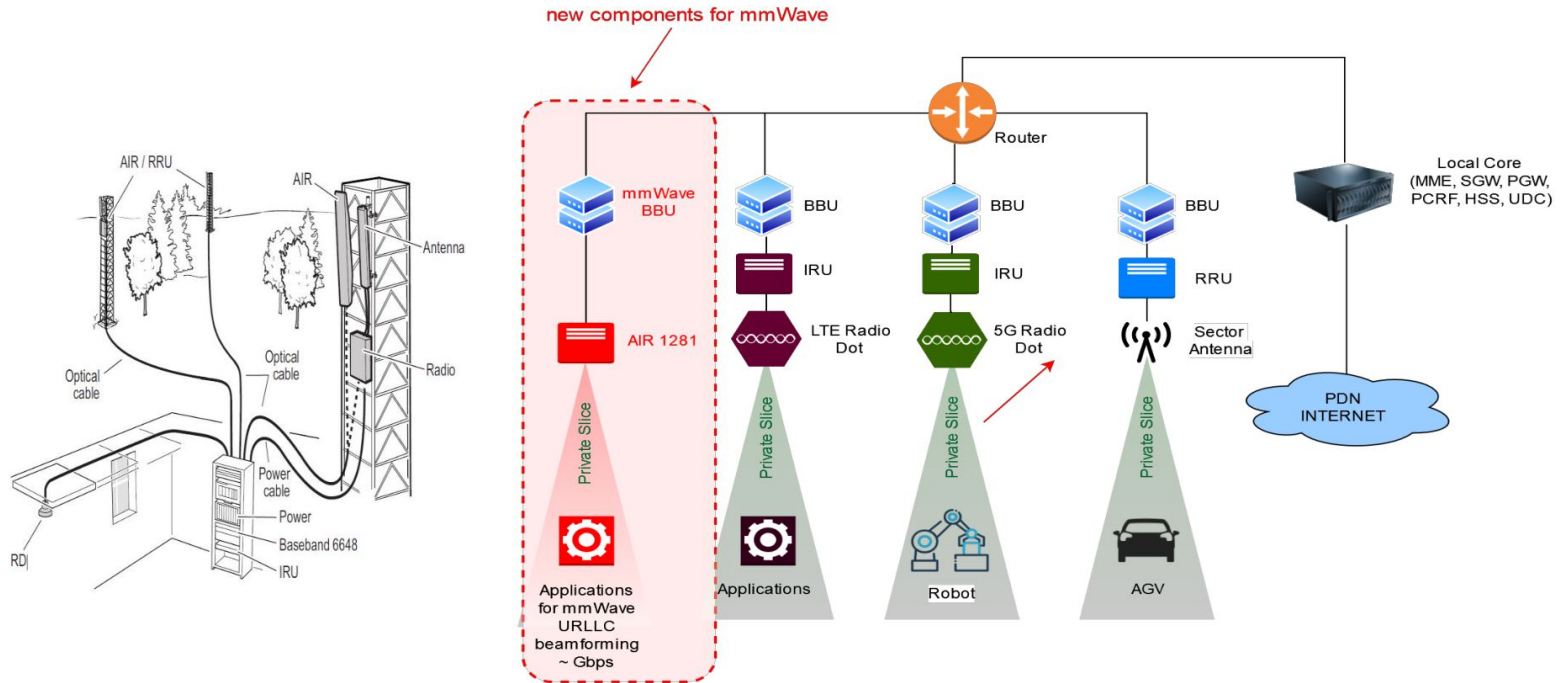
Quectel RM510Q-GL

- Form factor M.2
- 5G NR: n1/n2/n3/n5/n7/n8/n12/n20/n25/n28/n38/n40/n41/n48/n66/n71/n77/n78/n79/**n257/n258/n260/n261**
- 5G NSA mmWave: Max. 7.5Gbps (DL)/ Max. 2.9Gbps (UL)

- Radio capable of transmitting almost 3Gbps
- Persisting 5G core (Ericsson) firmware issues

```
------------------------------------------------------       Connecting to host 158.196.109.78, port 5201
Server listening on UDP port 5001                        [  5] local 158.196.246.58 port 59924 connected to 158.196.109.78 port 5201
UDP buffer size: 16.0 MByte                              [ ID] Interval           Transfer     Bitrate         Retr  Cwnd
------------------------------------------------------   [  5]   0.00-1.00   sec   113 MBytes   947 Mbits/sec    4    346 KBytes
                                                         [  5]   1.00-2.00   sec   112 MBytes   939 Mbits/sec    2    291 KBytes
Client connecting to 158.196.109.78, UDP port 5001       [  5]   2.00-3.00   sec   111 MBytes   934 Mbits/sec   38    284 KBytes
Sending 1400 byte datagrams, IPG target: 42.72 us (kalman adjust)  [  5]   3.00-4.00   sec   112 MBytes   935 Mbits/sec    2    296 KBytes
UDP buffer size: 16.0 MByte                              [  5]   4.00-5.00   sec   112 MBytes   936 Mbits/sec   11    267 KBytes
------------------------------------------------------   [  5]   5.00-6.00   sec   111 MBytes   933 Mbits/sec   20    328 KBytes
[  1] local 158.196.222.60 port 47599 connected with 158.196.109.78 port 5001  [  5]   6.00-7.00   sec   111 MBytes   931 Mbits/sec    2    341 KBytes
[  2] local 158.196.222.60 port 5001 connected with 158.196.109.78 port 40733  [  5]   7.00-8.00   sec   112 MBytes   935 Mbits/sec   36    286 KBytes
[ ID] Interval       Transfer     Bandwidth             [  5]   8.00-9.00   sec   111 MBytes   931 Mbits/sec    3    325 KBytes
[  1] 0.0000-1.0000 sec  31.3 MBytes   262 Mbits/sec     [  5]   9.00-10.00  sec   111 MBytes   933 Mbits/sec   30    438 KBytes
[ ID] Interval       Transfer     Bandwidth       Jitter    Lost/Total Datagrams  - - - - - - - - - - - - - - - - - - - - - - - - -
[  2] 0.0000-1.0000 sec  27.2 MBytes   229 Mbits/sec   0.042 ms 3238/23645 (14%)  [ ID] Interval           Transfer     Bitrate         Retr
[  2] 0.0000-1.0000 sec  170 datagrams received out-of-order  [  5]   0.00-10.00  sec  1.09 GBytes   936 Mbits/sec  148             sender
[  1] 1.0000-2.0000 sec  31.2 MBytes   262 Mbits/sec     [  5]   0.00-10.04  sec  1.09 GBytes   930 Mbits/sec                  receiver
[  2] 1.0000-2.0000 sec  31.3 MBytes   262 Mbits/sec   0.039 ms 0/23409 (0%)
[  1] 2.0000-3.0000 sec  31.3 MBytes   262 Mbits/sec
[  2] 2.0000-3.0000 sec  31.2 MBytes   262 Mbits/sec   0.041 ms 0/23405 (0%)
[  1] 3.0000-4.0000 sec  31.2 MBytes   262 Mbits/sec
[  2] 3.0000-4.0000 sec  31.2 MBytes   262 Mbits/sec   0.042 ms 0/23403 (0%)
[  1] 4.0000-5.0000 sec  31.3 MBytes   262 Mbits/sec
[  2] 4.0000-5.0000 sec  31.3 MBytes   262 Mbits/sec   0.043 ms 0/23408 (0%)
[  1] 5.0000-6.0000 sec  31.2 MBytes   262 Mbits/sec
[  2] 5.0000-6.0000 sec  31.3 MBytes   262 Mbits/sec   0.040 ms 0/23406 (0%)
[  1] 6.0000-7.0000 sec  31.2 MBytes   262 Mbits/sec
[  2] 6.0000-7.0000 sec  31.2 MBytes   262 Mbits/sec   0.040 ms 0/23405 (0%)
[  1] 7.0000-8.0000 sec  31.3 MBytes   262 Mbits/sec
[  2] 7.0000-8.0000 sec  31.3 MBytes   262 Mbits/sec   0.040 ms 0/23408 (0%)
[  1] 8.0000-9.0000 sec  31.2 MBytes   262 Mbits/sec
[  2] 8.0000-9.0000 sec  31.2 MBytes   262 Mbits/sec   0.040 ms 0/23405 (0%)
[  1] 9.0000-10.0000 sec  31.3 MBytes   262 Mbits/sec
[  1] 0.0000-10.0001 sec   313 MBytes   262 Mbits/sec
[  1] Sent 234061 datagrams
[  1] Server Report:
[  1] 0.0000-9.8626 sec   291 MBytes   247 Mbits/sec   0.045 ms 16442/234060 (7%)
[  1] 0.0000-9.8626 sec  146 datagrams received out-of-order
[  2] 9.0000-9.9918 sec  30.9 MBytes   262 Mbits/sec   0.132 ms 0/23167 (0%)
[  2] 0.0000-9.9918 sec   308 MBytes   259 Mbits/sec   0.132 ms 3238/234061 (1.4%)
[  2] 0.0000-9.9918 sec  170 datagrams received out-of-order
```

Stay tuned!

Questions?

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