Keys for scalable M2M/IoT networks

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- SIGFOX in few words
- M2M & IoT : The “arena”
- The Ultra Narrow Band Approach
- Cognitive SDR
- Backend : The forgotten essential element
- Demo’s
- Q&A’s

SIGFOX in few words

- **Founded in 2008. Now 50 collaborators.**
- **SDR and UNB fundamental radio blocks designed between 2008 and 2010**
- **First success in M2M market**
- **End 2010 : Association with Ludovic Le Moan, founder of Anywhere Technology (now Sierra) and co-founder of ScoopIT**
- **The “New SIGFOX” : Orientation to M2M/IoT network technology and operator business model**
- **2011 : first large subscription contracts signed. Development of partner eco-system**
- **2012 : SIGFOX moves to TIC-Valley**
- **2013 : France fully covered. Netherland and Russia signed. Spain and others to come.**
- **2014 : Spain started. Germany, UK and Benelux to come soon… Stay tuned !**

TiC valley
concentré d'entreprises innovantes

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M2M / IoT : The “Arena”

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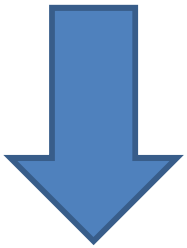
Quick panorama of today's M2M/IoT

	Pro's	Con's
Cellular : GPRS, 3G … Optimized 4G in few years	Large networks exist	Cost.**Consumption!** (terminals must be disciplined)
PMR : Mobitex, Tetra, specific	Large networks exist. Reliable	**High cost**. Dedicated to Pro
ISM : Proprietary, mesh, ZigBee…	Low cost	No clear standard. Often too simple. **Not scalable**
Satellite	Large coverage	Relatively high cost. **Not flexible**

Key facts about available spectrum

- Cellular spectrum is, and will stay very expansive
- Private spectrum as well
- ISM spectrum is not large and drastically limited and constrained (power, duty cycle…)
- TV White space are not global, if not just a “Mirage”
- Potential future specific allocations for M2M will take a long time, as ever (10 years ?)



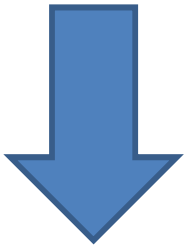
- **You should better get organized for a maximum optimization !!!**

Key goals for tomorrow's M2M / IoT

- Low cost … And even ultralow cost
- Ultra low current drain
- Consequence of above : Keep devices as "low talker" as possible, and avoid to "discipline" them through complex protocol…
- However : Need for high scalability … Ten's of billion of objects
- Keep CAPEX and thus infrastructure as low cost as possible at startup
- Standardize !
- Many things to be reinvented compared to classical networks !

The paradoxes

- You need large cells for minimum CAPEX, thus long ranges
- But you want low power
- And despite large cells, you still want scalability on tiny spectrums, thus very high capacity per MHz
- However … devices are not disciplined for low consumption and low complexity/cost …



- **It seems you need to put intelligence in the network and use advanced techniques like Cognitive SDR !!!**

Behind the technology : The rational

- Main objective : Keep network cost as low as possible

  Most actors in M2M still think in a peer to peer way. But the essential "market booting factor" is "having a low cost wide area network, transparent to final customer"

- cells as large as possible
- But with as high capacity as possible
- Optimize the resource. Thus please Be at Nyquist criteria ! X bit per second = X Hz bandwidth
- You need high performance high selectivity SDR cognitive able to handle a large number of signals in parallel : That's where you can put your effort and money !
- Design the clever backend that fits with it, so that it is seamless to final customer

- Second objective : low cost / low consumption modems
- Keep it as simple as possible
- Simplify protocol, particularly for low volume transactions
- Focus on the low data volume market and operate modems at low datarate to drastically improve budget link. Cellular is 140/150 dB. Let's go for 160 dB despite 20 dB less RF power
- Network should not ask modems for long disciplining processes. But it should be at the service of modems to compensate for their imperfections, contributing to their low cost
- Develop ecosystem and applications

YOU CAN NOW FINALLY BOOT THE M2M MARKET…

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Summary of rational

- Large cells but high capacity → Try to be @ Nyquist for very low datarates
- You must implement high selectivity's or high “logic channel” separation
- Do not discipline your devices. Keep them simple
- But sophisticate your infrastructure to push service quality as high as possible with deep possibilities of further upgrade
- Particularly, design your nodes as “multi-instantiation” as possible
- Optimize your budget links as far as possible
- Do everything you can to migrate complexity from device to infrastructure
- **All choices must be coherent within the complete system**

- **Once again, bet on cognitive SDR + agile backhaul**

Ultra Narrow Band Approach

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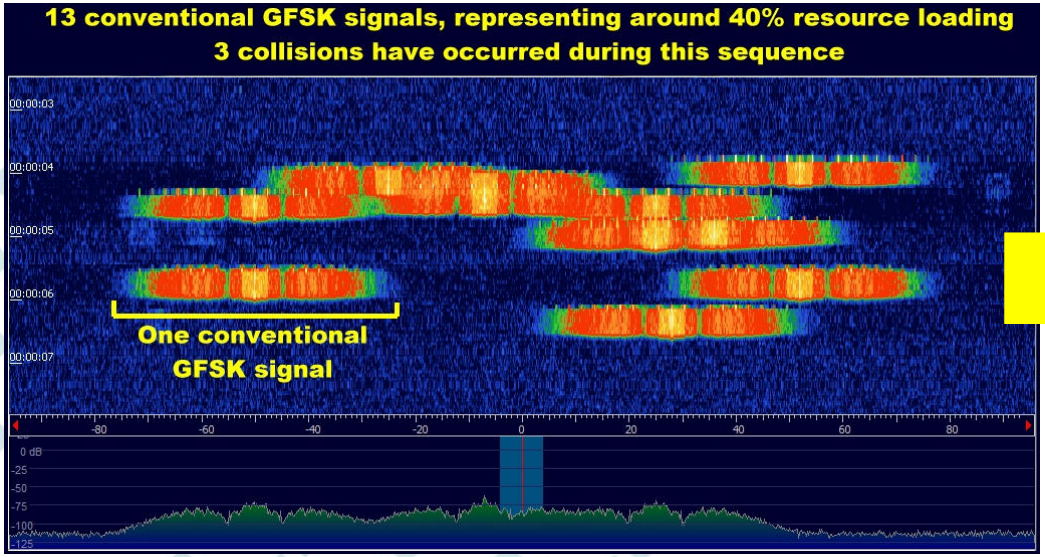
Network cost : Why Ultra Narrow Band ?

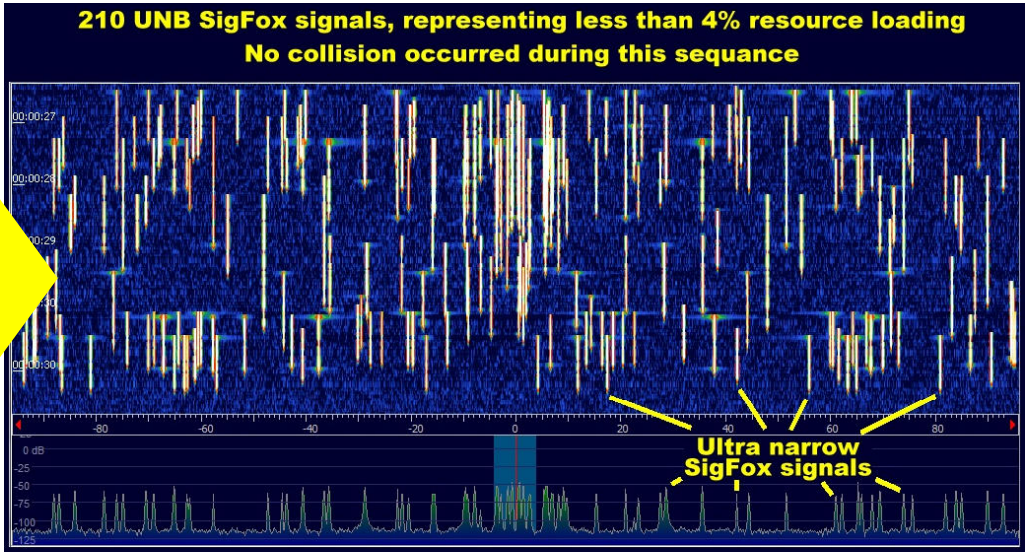
- How to optimize your available spectrum ?

Conventional signals are stones (the protocol) containing a grain of sand (your information). You should rather fill directly with sand !

Should go

To this





- But Narrow Band techniques have been almost abandoned for more than 40 years. Why ?
- Because the more you work narrowband, the more tuning is complex, the more stability issues are of first importance… And thus the more expansive are your systems ! **But SigFox succeeded to achieve it at low cost…**

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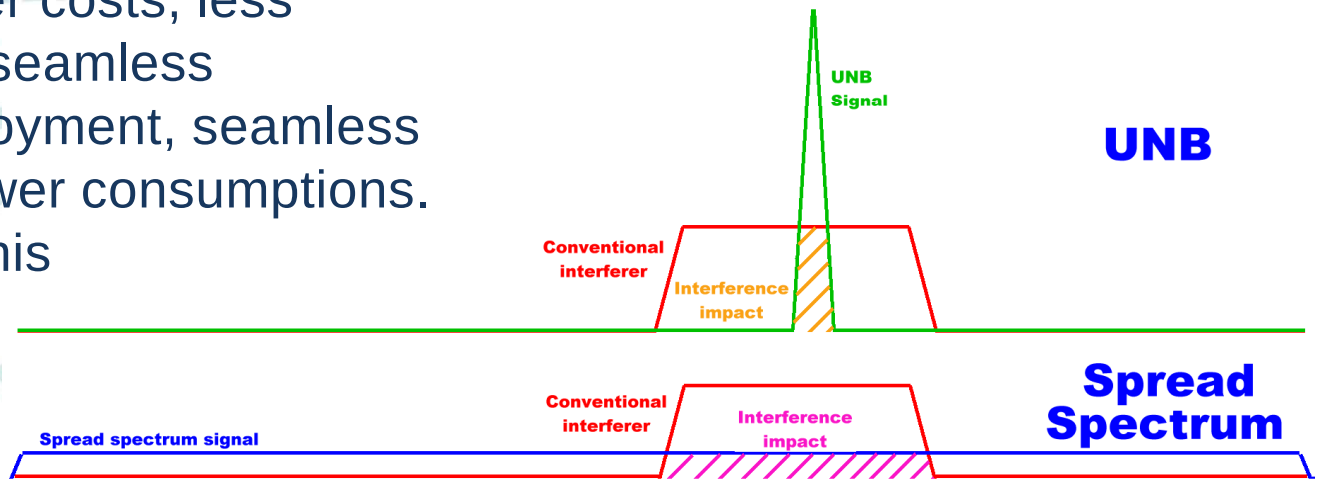
But then, why not other techniques ?

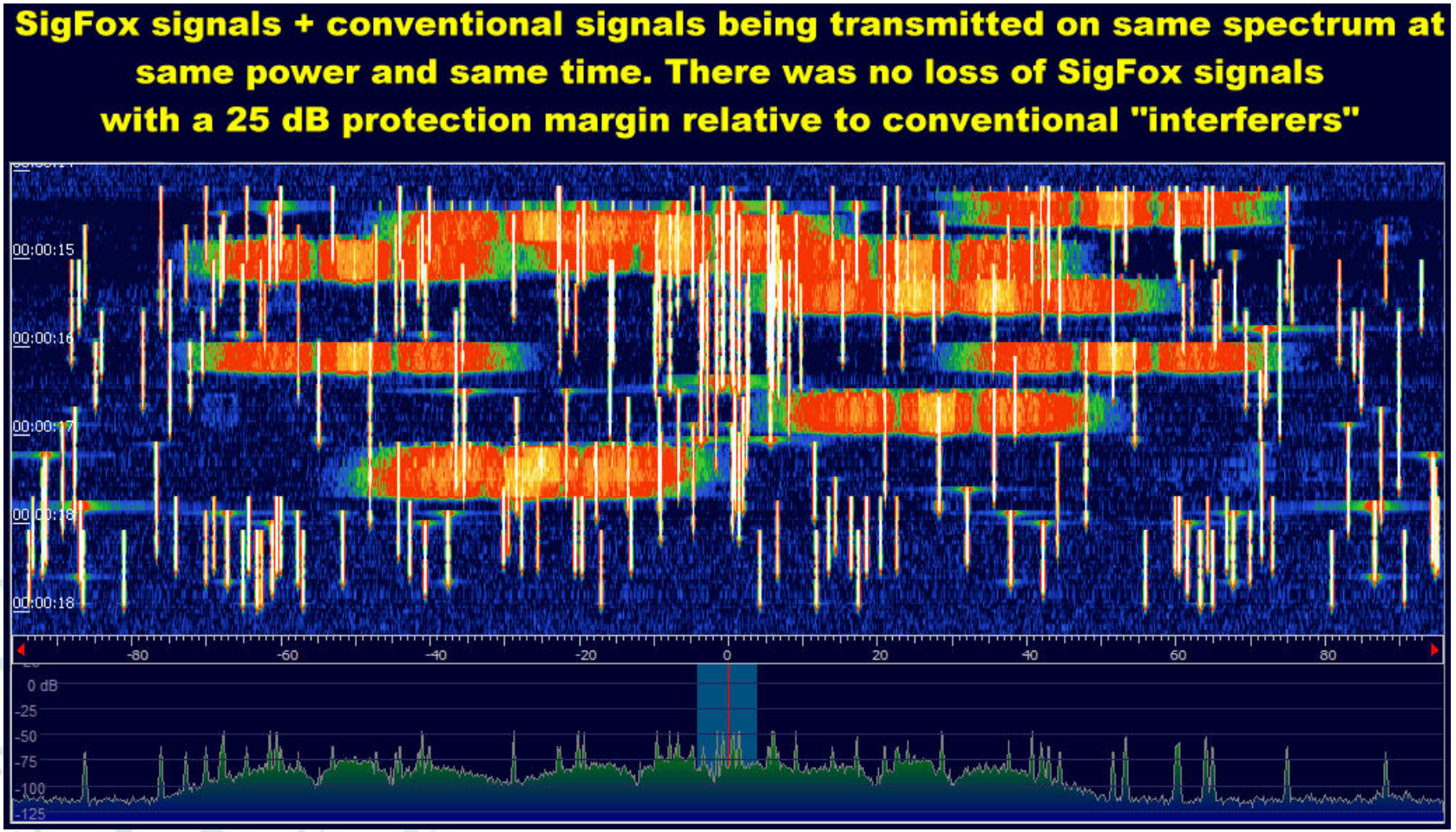
- Spread Spectrum is an other option and it helps get rid of stability issues
  - It is also a good technique for interference robustness.
  - In fact UNB and SS are dual technique regarding interferences
  - DSSS or OSSS often bring a certain degree of flexibility by essence
- However, since you are able to solve the tuning issue at low cost, UNB might be superior on :
  - Simplicity of terminals
  - Fact that SS requires disciplining terminals for spreading code attribution
  - Better capacity : Since you are able to achieve UNB selectivity, the narrower you operate, the higher is capacity
  - Additionally, the narrower you operate, the lighter is protocol, going down to zero quickly
  - No frequency/channel management. Terminals are “free running”

- **<u>Conclusion</u>** : if you solved the known UNB issues, you will get better resource optimization for much lower costs, less protocol overhead, if any, seamless deployment and post deployment, seamless connections and lower power consumptions. SDR is a way to achieve this



Are you sure selectivity/capacity is there ?

- Yes, beyond rigorous scientific study, SigFox has developed a complete set of test equipments allowing full network loading tests (with presence of interferers) **on real hardware**, before it can even “just starts to occur” on the field.



- **Typically Up to 3 Million devices per day on a single BS for 3 transactions per device per day and only 8% spectrum loading**

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How did SigFox solved the UNB issues?

- Do not care about terminal “imperfections”, like static or dynamic stability, among others. Put effort on station’s SDR software that will compensate for it !
- Highly multisession thanks to time critical software coding techniques : You cans handle thousands of simultaneous signals
- High dynamic BS radio (120 dB) is needed for above purpose, specially when installed at top of a large cell where electromagnetic environment is “aggressive”.

AND WHAT ABOUT UNB ISSUES ON TERMINALS…

- Uplink is extremely simplified. Almost whatever commercial chip can be used. Dynamic frequency instabilities are corrected in the BS. Terminal is free to impose its frequency hopping.
- Bidirectional terminal’s receivers do not need BS sophistication because, once again, network compensates for their weaknesses. You can operate UNB without stability concern.

Cognitive SDR

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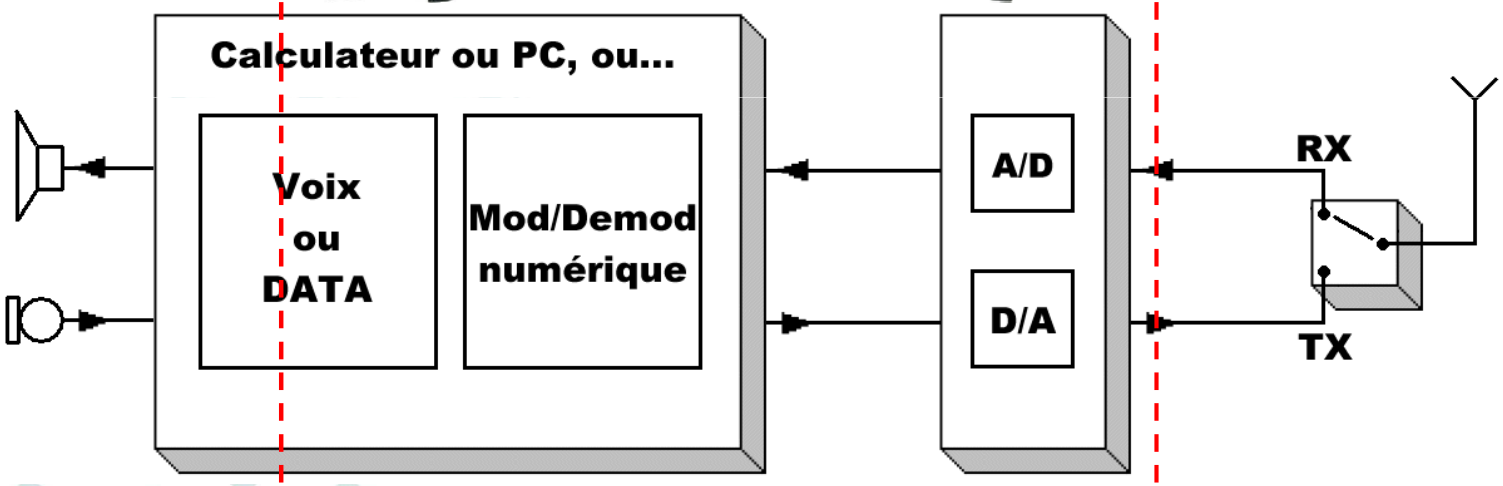
SDR in 2 words

- Some history :
- SDR concept appears in the 80's (1984)
- Labs like « Software Radio Proof-of-Concept laboratory » in US, or « German Aerospace Research Establishment » or companies like Raytheon, Thomson, Rockwell start prototypes.
- It is admitted Dr Joseph Mitola was the first in 1991 to introduce terms of « SDR », as well as « cognitive »…Considered as the « pope » of SDR, he has for example worked on projects like SPEAKeasy II for US departments
- First 70 Msamp/s digital IF cellular base station introduced on the market around 2000
- Since then, a good example of SDR devices : Our cell phones…

SDR, or the quest of « saint – Graal »

You want to push channel filtering and « specialization » as far as possible

And you want to get rid of RF…



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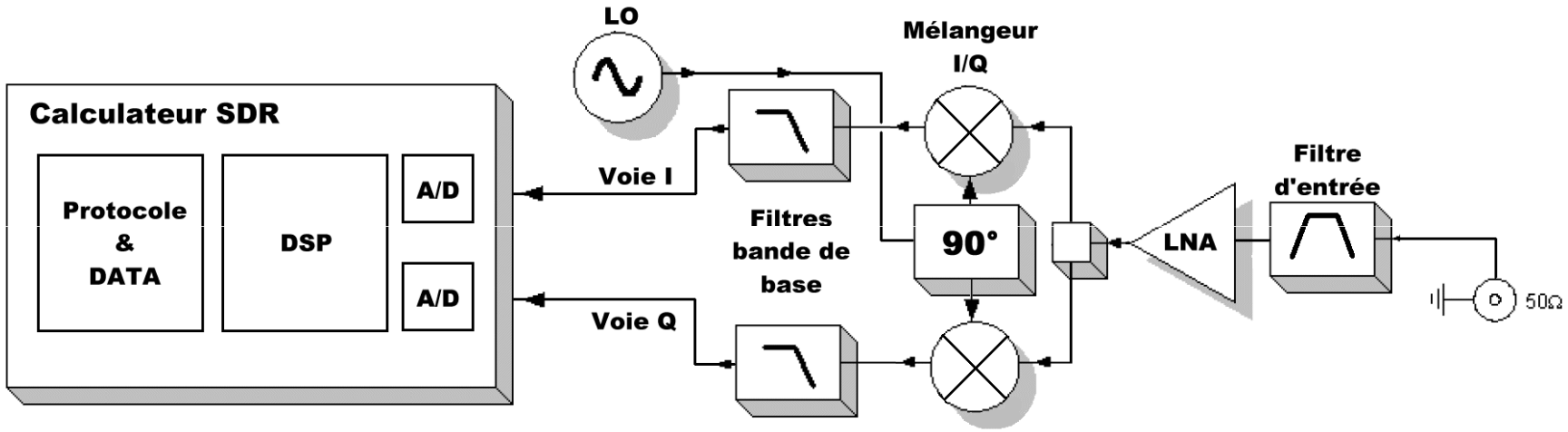
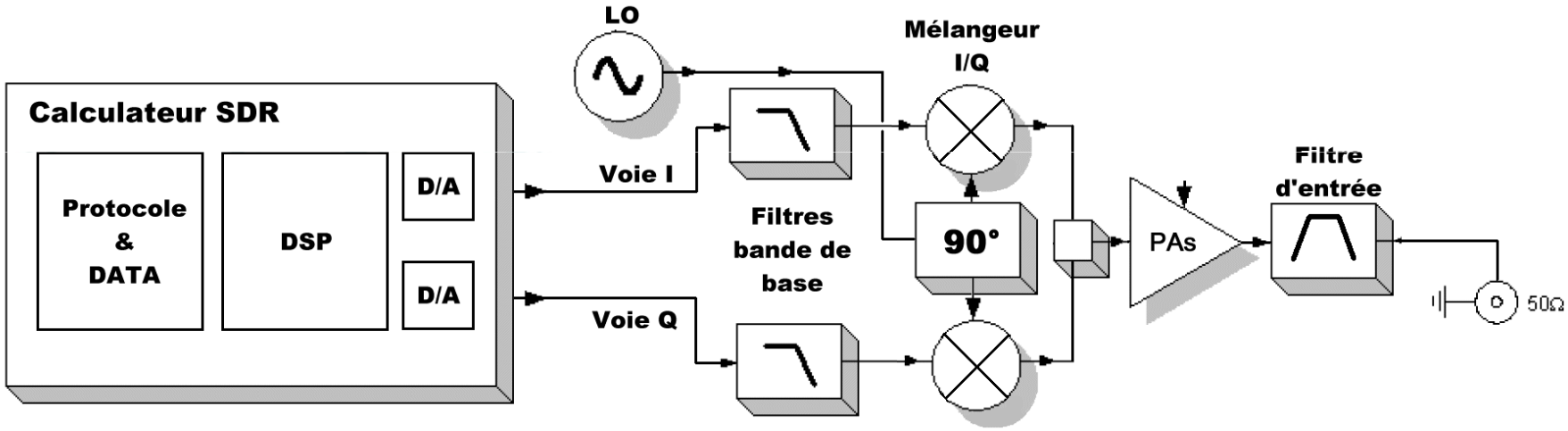
A practical SDR radio… in 2 words

But for now … Need some compromize



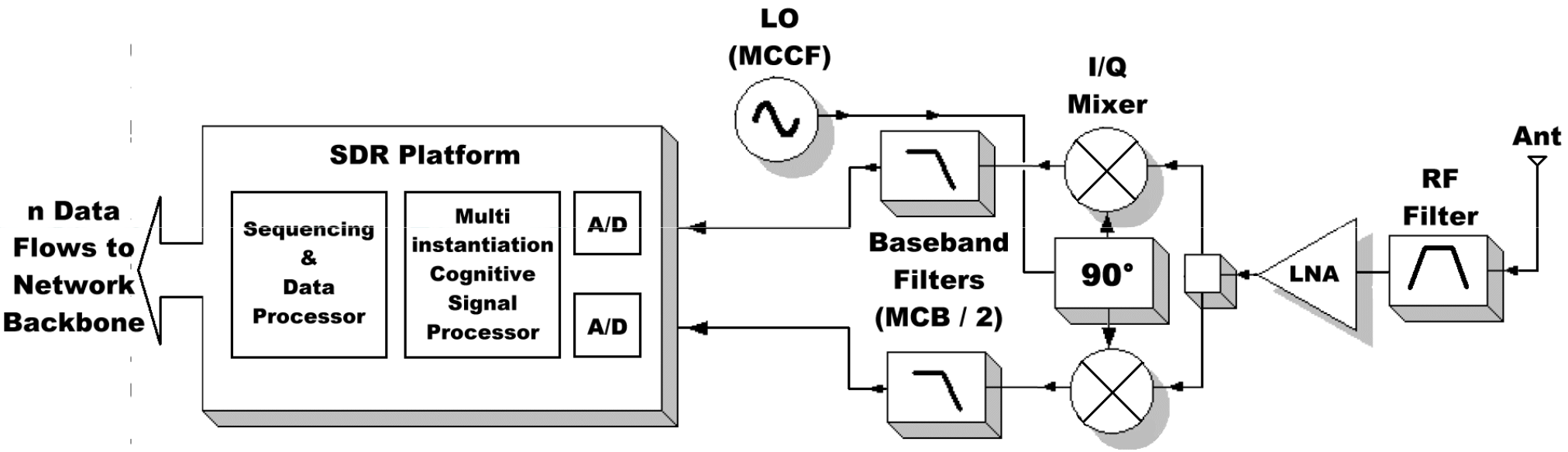
Exemple de récepteur SDR, à partir d'une RF vectorielle



Exemple d'émetteur multisignaux SDR à partir d'une radio vectorielle

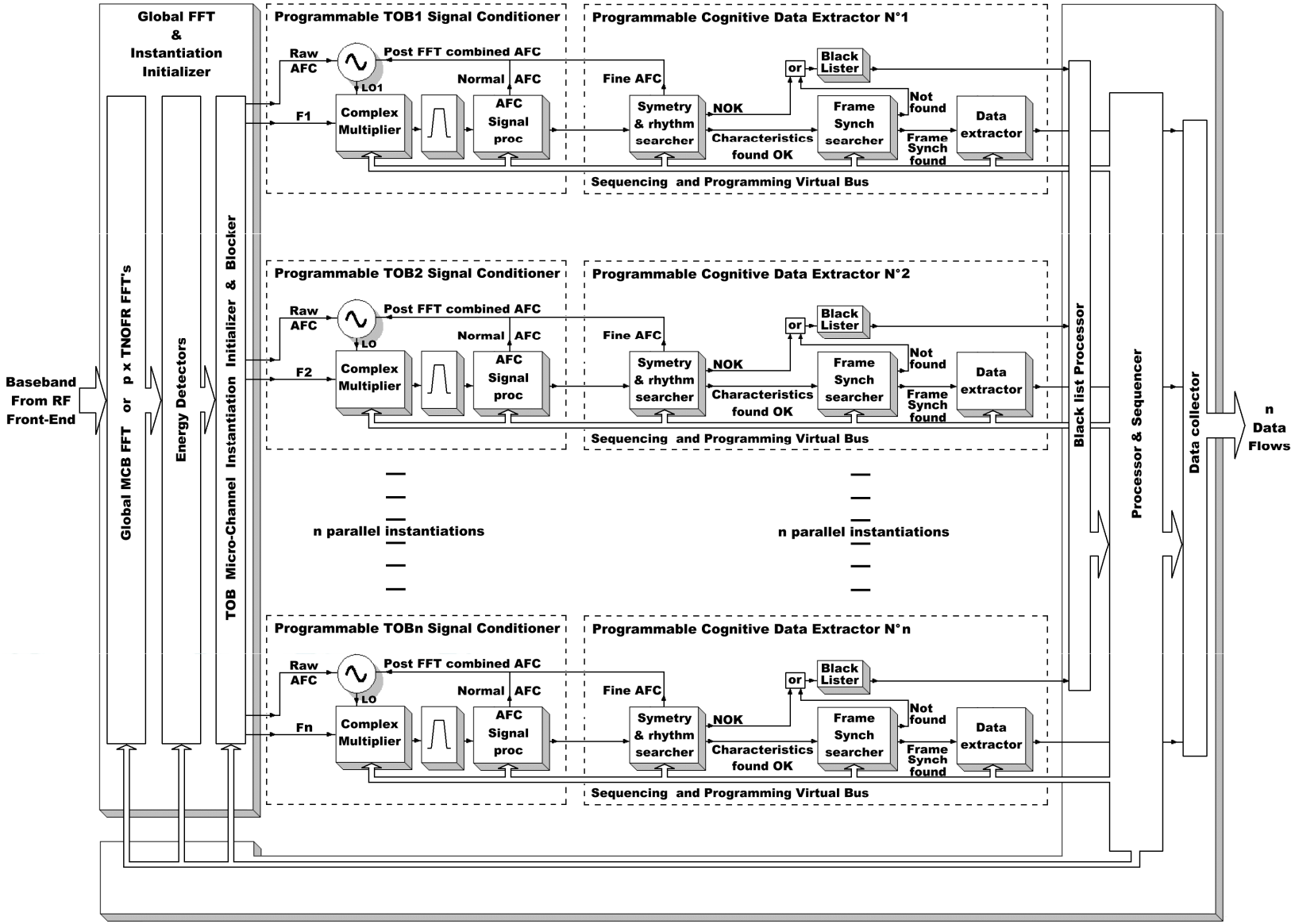
A Cognitive multi-instantiation SDR

- A common RF and A/D for multiple software instantiations, each of them dynamically “discovering”, identifying and demodulating a specific UNB signal among a plurality of others → One RF = N receivers
- Same principle for transmission : Compute a complex multi-signal (multi-carrier), sent to a unique D/A & RF



A Cognitive multi-instantiation SDR

- An example of a multi-branch demodulator Software implementation



Backend : Or the forgotten element

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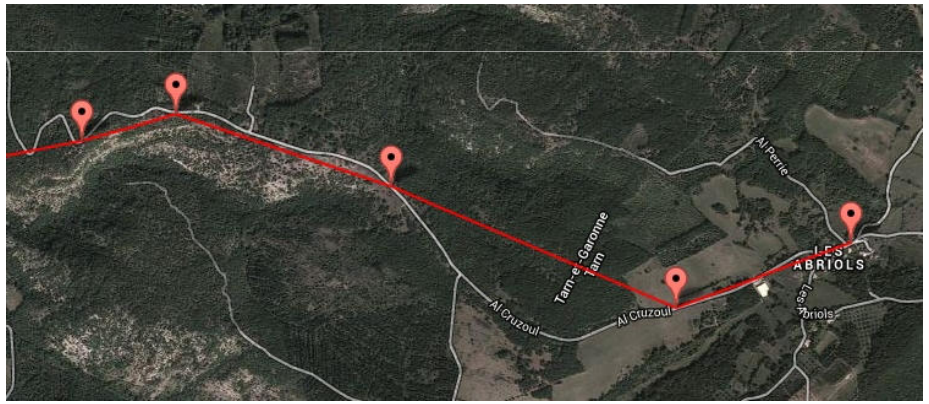
Do not neglect Network “backend”

- **Backend is the “brain” of your SDR infrastructure :**
  - **Provide end to end seamless connectivity to customer.**
  - **Data management, web services, billings**
  - **BS, site and network asset control, management and statistics**
- **Additional potential features:**
  - **Geo-location.**
  - **Network registration and population management.**
  - **Roaming strategy.**
  - **Security and surveillance algorithm.**
  - **Coverage simulation tool**
  - **QoS alerts based on metadata**
  - **Possibilities of spectrum remote analysis. Leads to manual or automated spectrum and jamming alerts.**
  - **Possibilities of improved performances through signal post processing on servers taking advantage of collaborative property of the network.**

Everything you can log brings value

Time	Delay (s)	Header	Data / Decoding	TAP - Signal (dB) - Freq (MHz) - Rep	Callbacks
2013-06-10 02:29:11	1.4	0004	303041384323 ASCII: 00A8C#	009A 16,3 868,1827 2 00C4 27,5 868,1830 3 0123 11,5 868,1823 2 0063 13,2 868,1829 2	N/A
2013-06-08 13:05:51	< 1	0024	323232324322 ASCII: 2222C"	00C4 33,7 868,1829 3 018E 12,2 868,1826 3 009A 7,9 868,1824 2	N/A

Network redundancy



Geolocation

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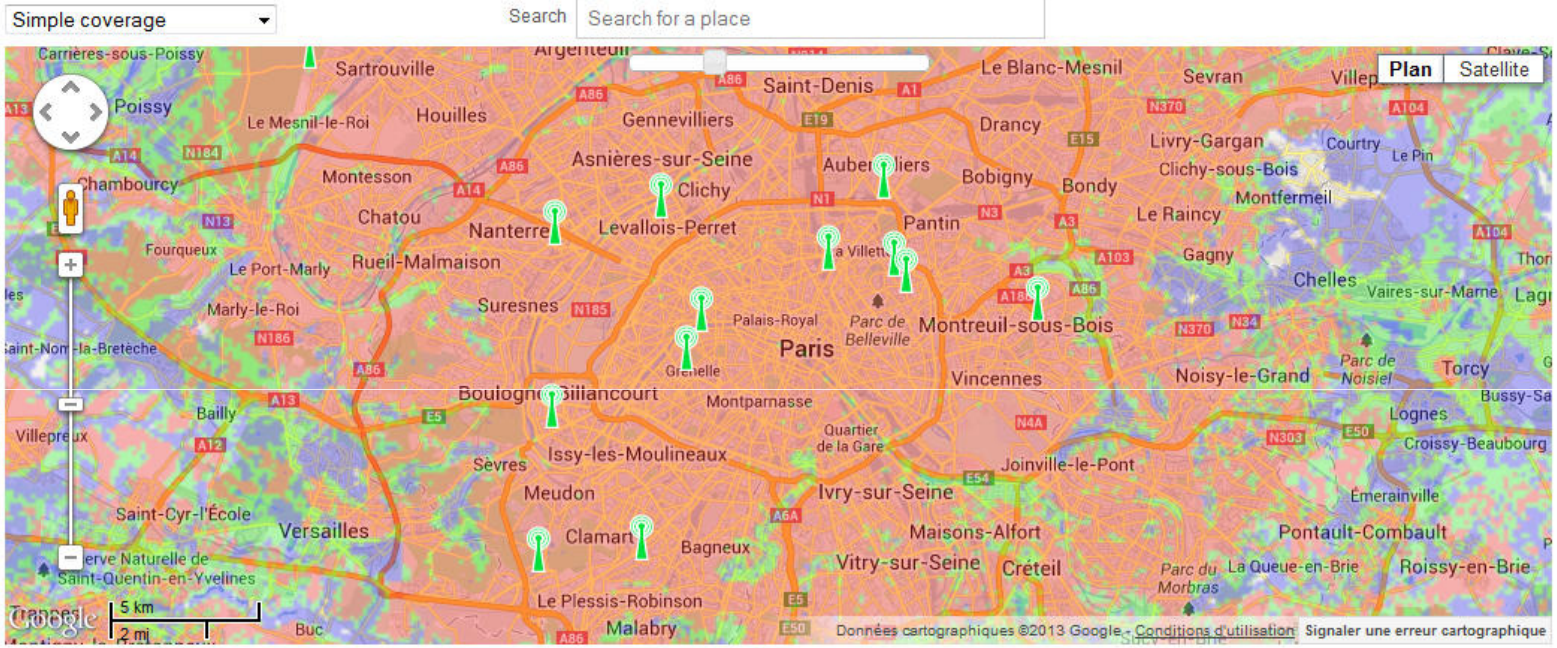
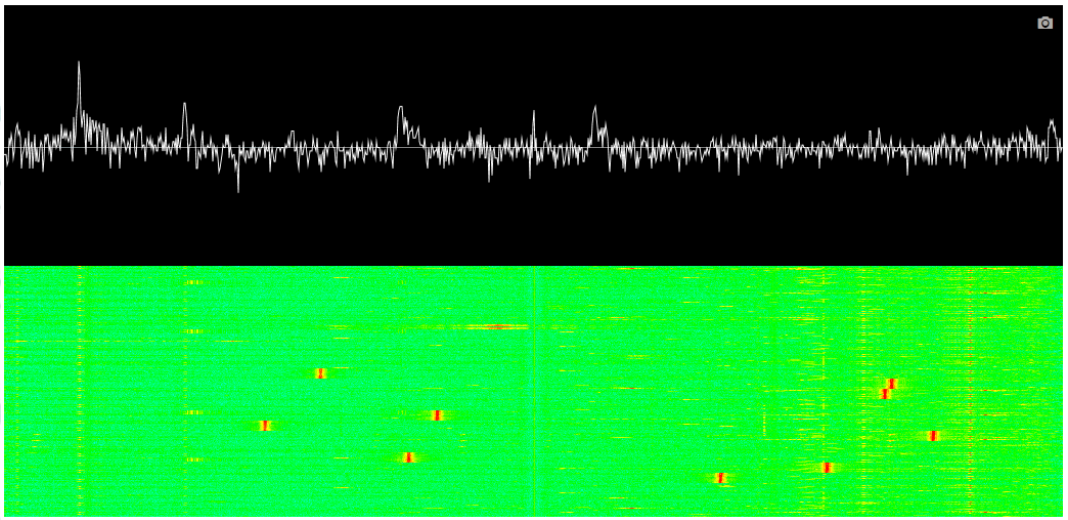
Do not neglect Network “backend”



Example of embedded network coverage simulation



Remote Spectrum analysis

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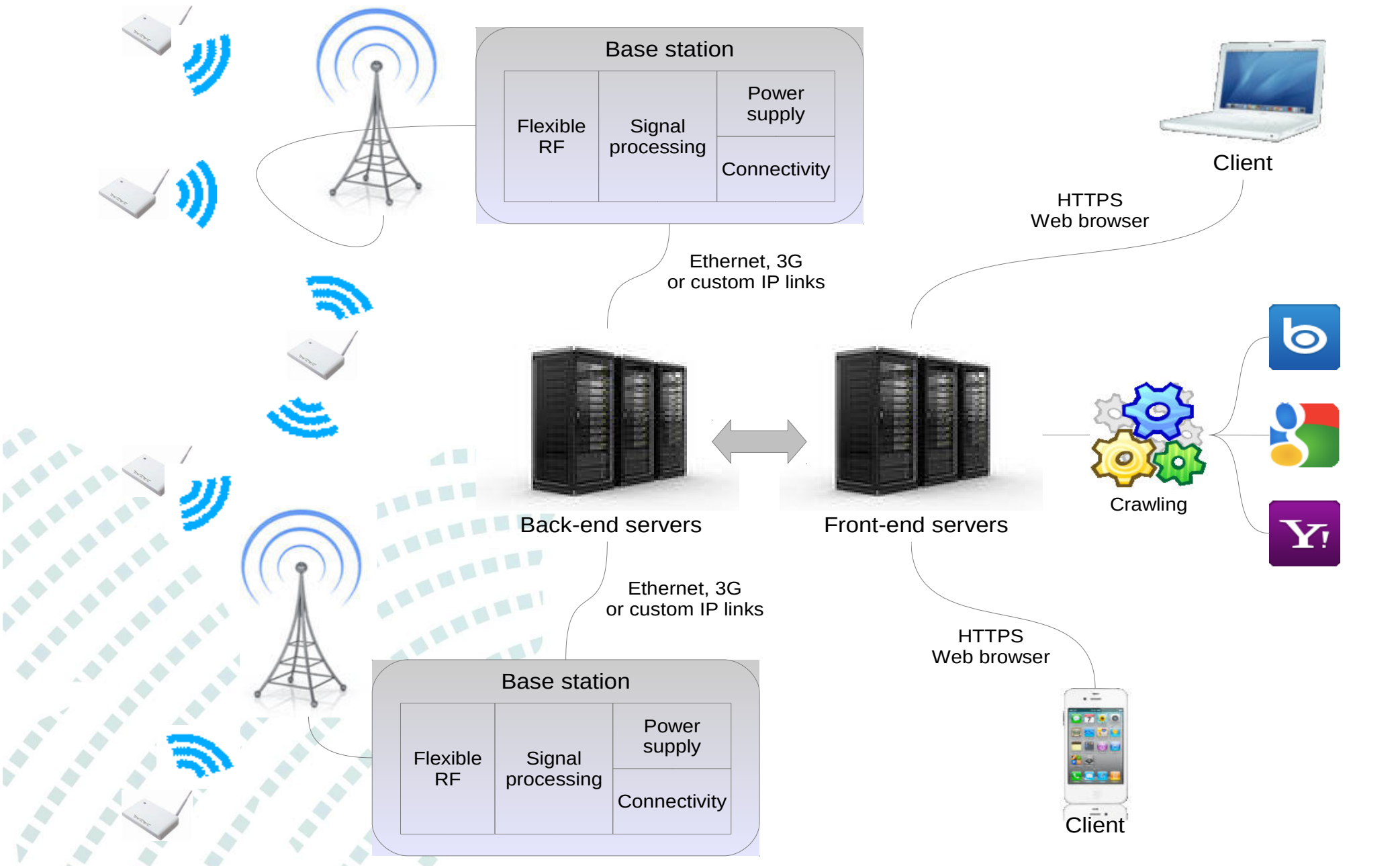
An example : SIGFOX network



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Demo’s / Q & A

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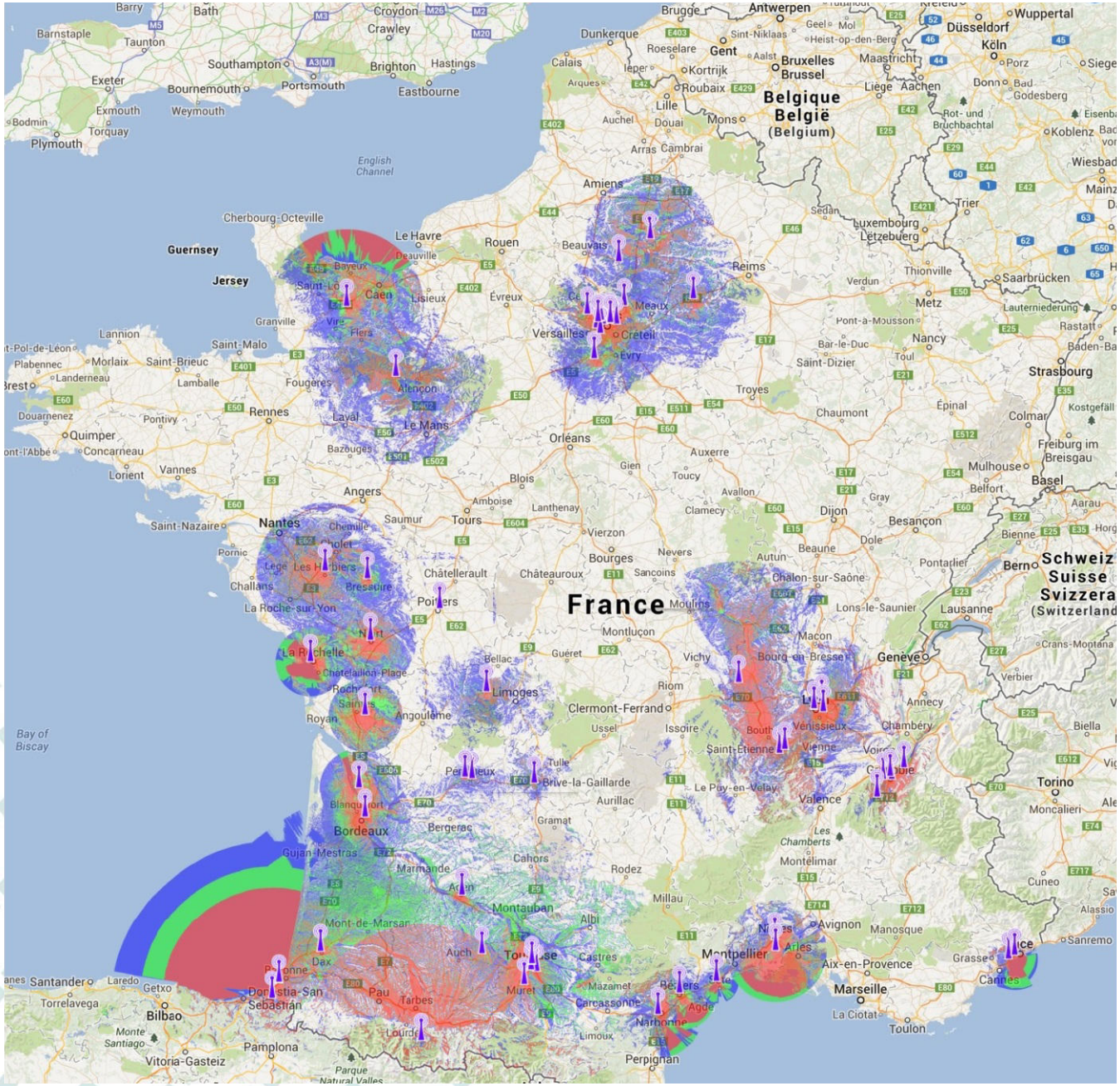
France coverage 01-01-2013

- Base station deployed : 57 u
- Coverage at -142 dBm (Typ budget link around 160 dB)
  - 26% of the territory
- Coverage at -120 dBm (22 dB margin on above BL)
  - 12% of the territory



France coverage 01-01-2013

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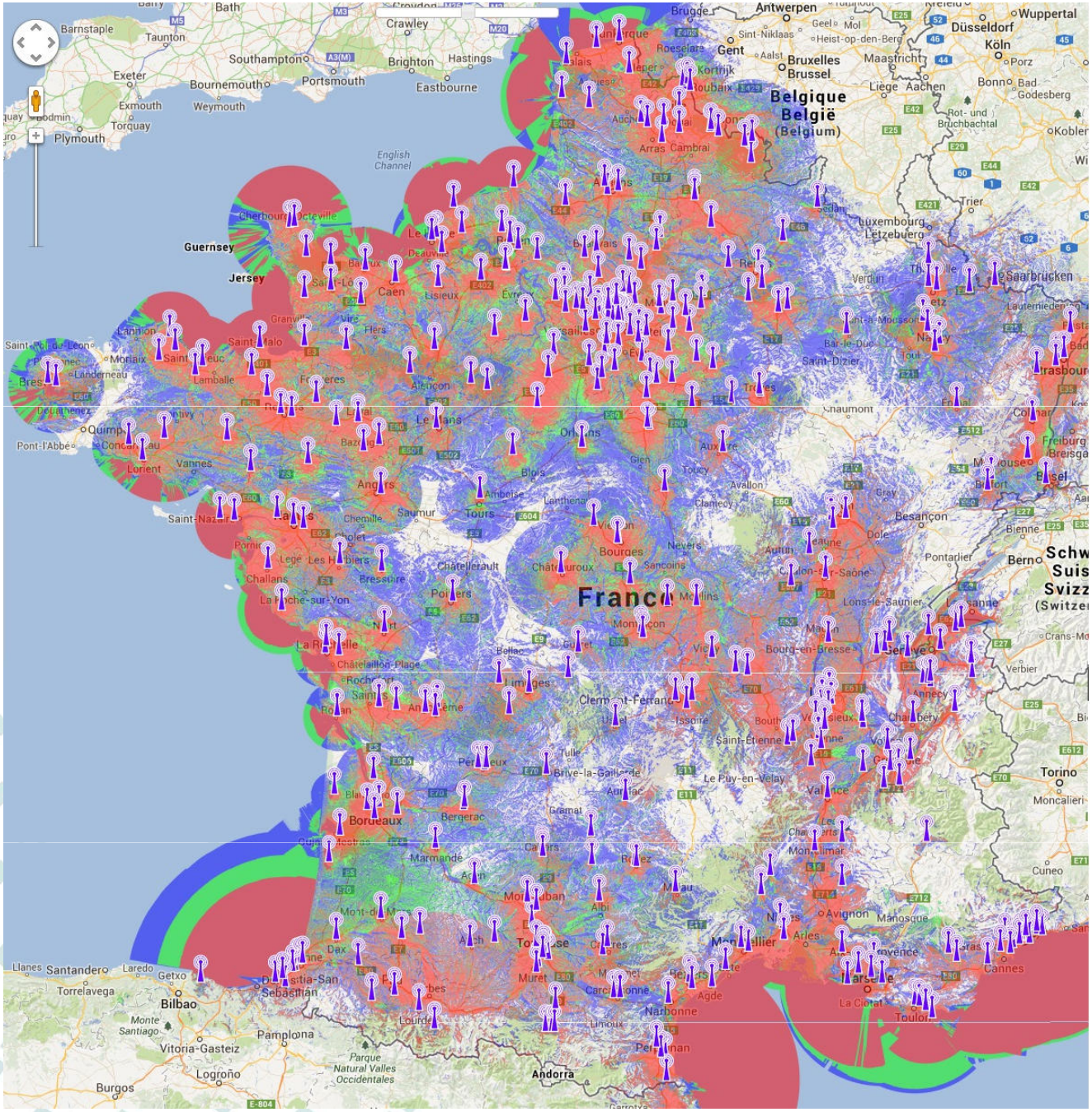
France coverage 08-31-2013

- Base station deployed : 396 u
- Coverage at -142 dBm (Typ budget link around 160 dB)
  - 72% of the territory
- Coverage at -120 dBm (22 dB margin on above BL)
  - 44% of the territory



France coverage 08-31-2013

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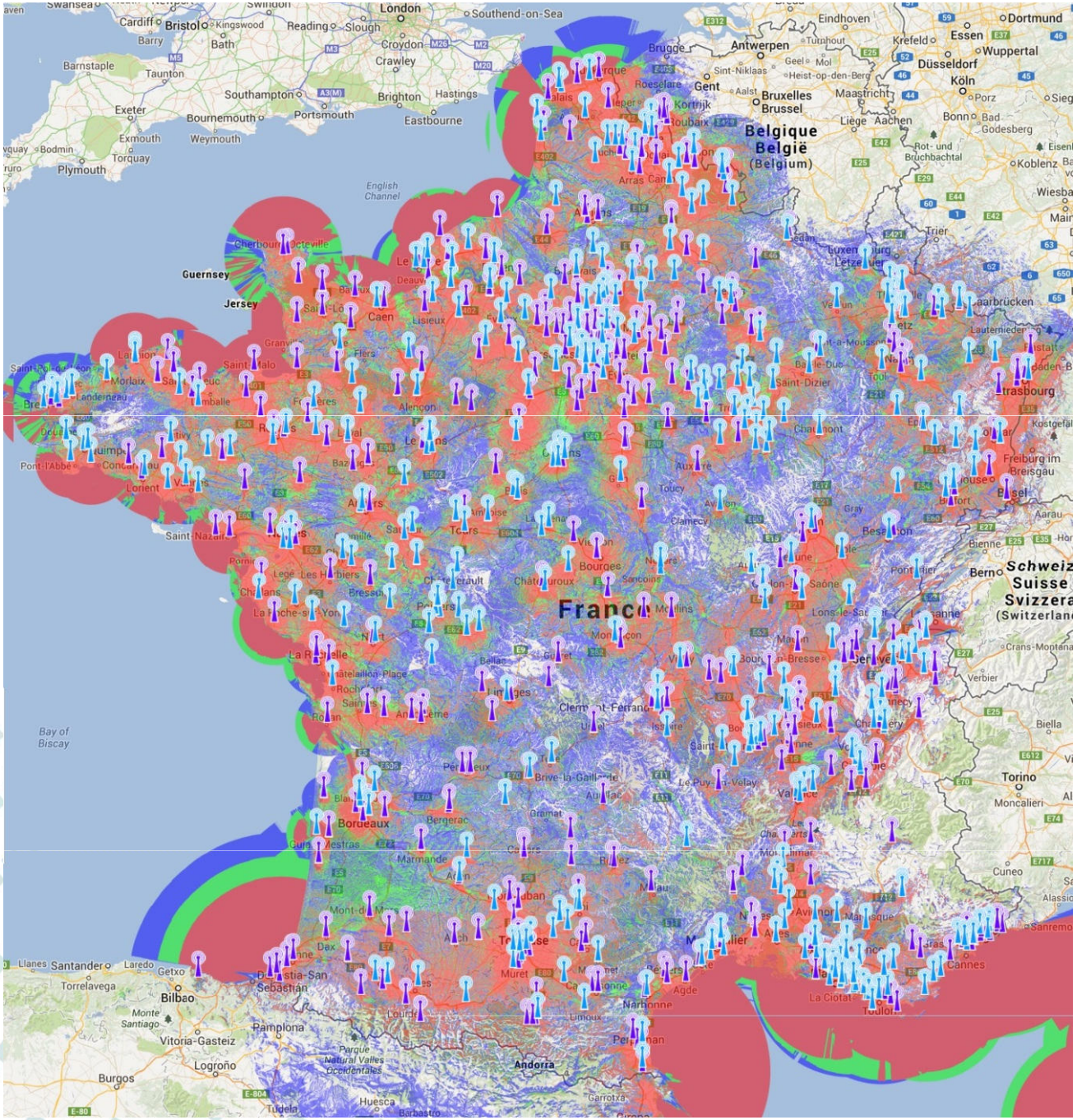
France coverage 12-31-2013

- Base station deployed : 770 u
- Coverage at -142 dBm (Typ budget link around 160 dB)
  - 83% of the territory
- Coverage at -120 dBm (22 dB margin on above BL)
  - %55 of the territory



France coverage 12-31-2013

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Thank you