The wireless Internet of Things:
Spectrum utilisation and monitoring

Ir. Tommy van der Vorst

September 14, 2016

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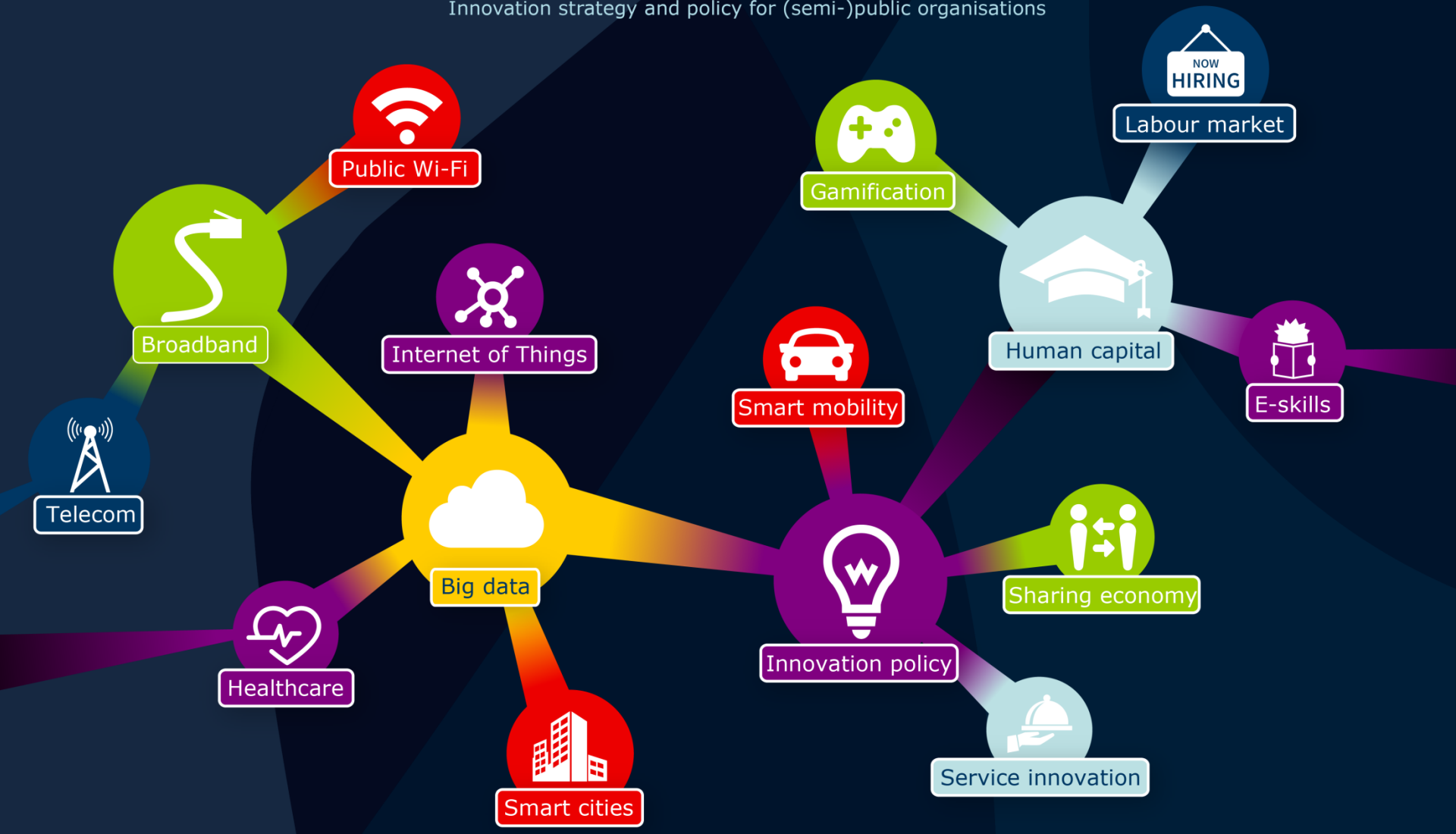
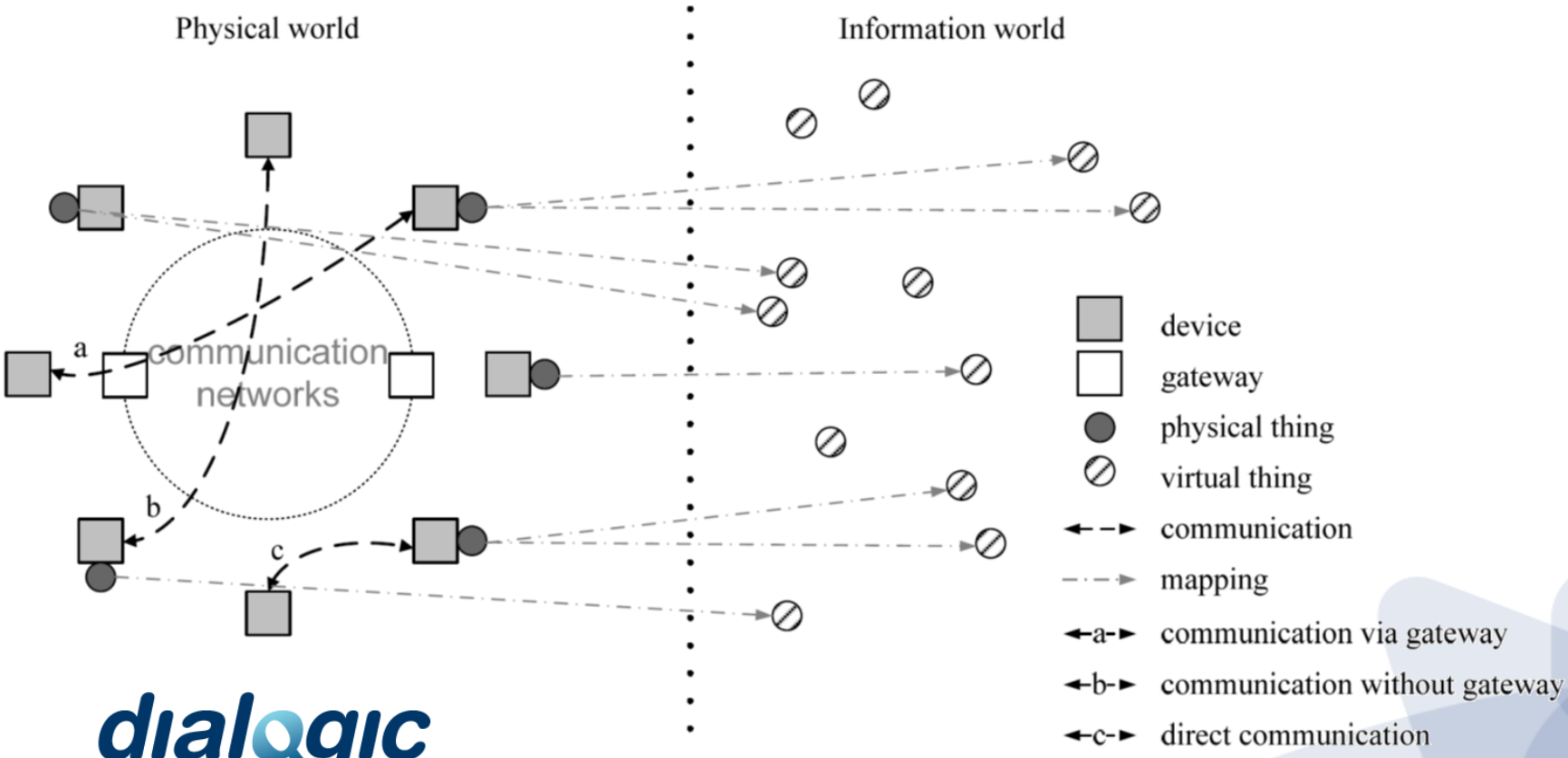
Innovation strategy and policy for (semi-)public organisations



What will be the impact of connectivity for the wireless Internet of Things (IoT) on the spectrum below 1 GHz?

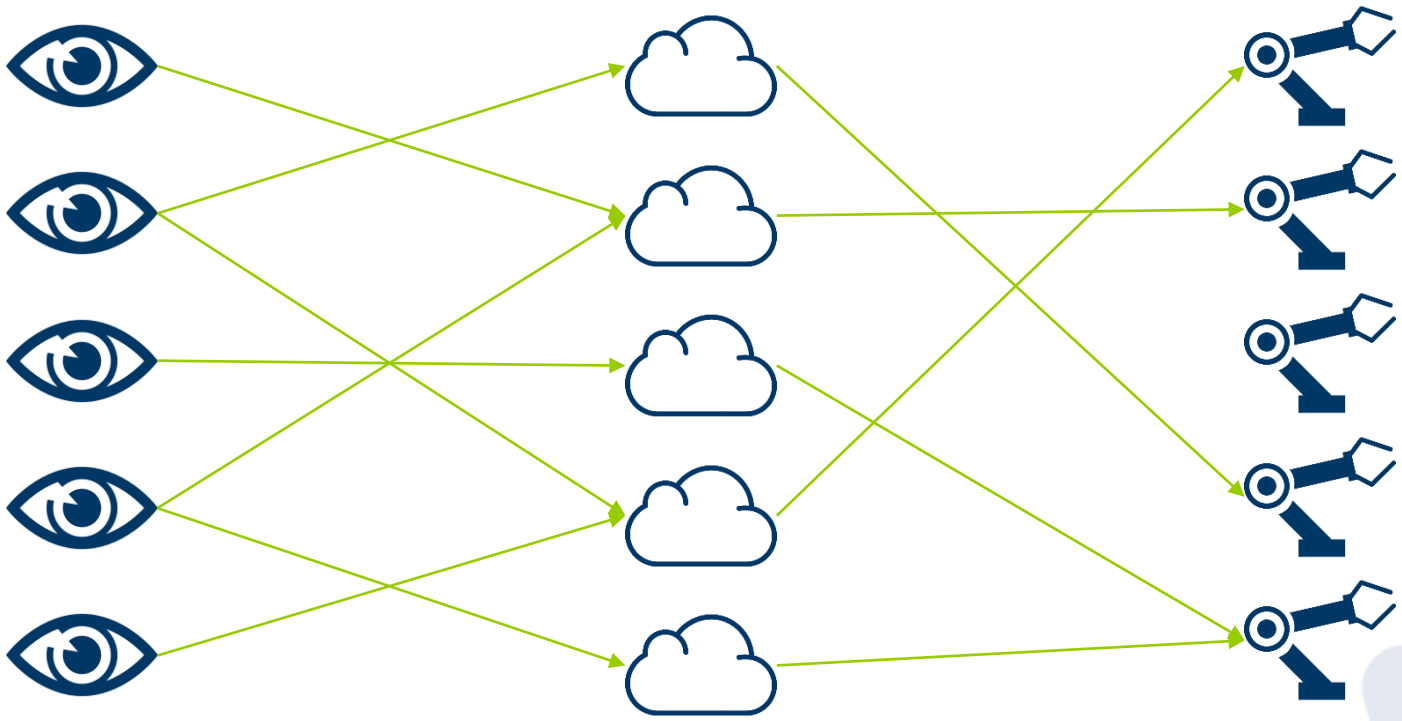
Internet of Things according to ITU

More and more physical 'things' are represented virtually in an 'information world' (aka the internet)



Internet of Things: why bother?

Smarter applications by (1) leveraging more sensor data, (2) perform more intelligent analyses, and (3) coordinate actuation.



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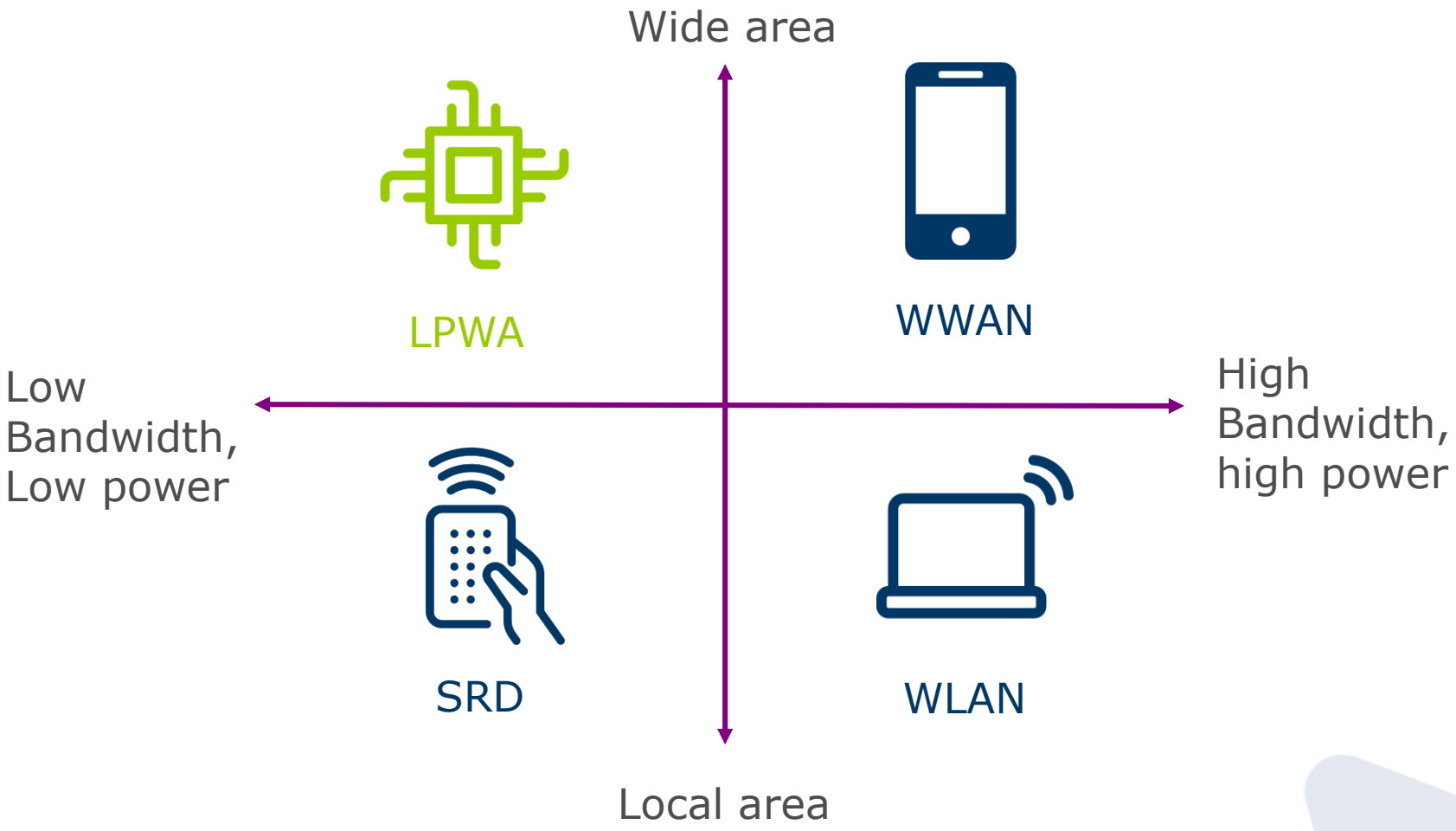
Levels of scale



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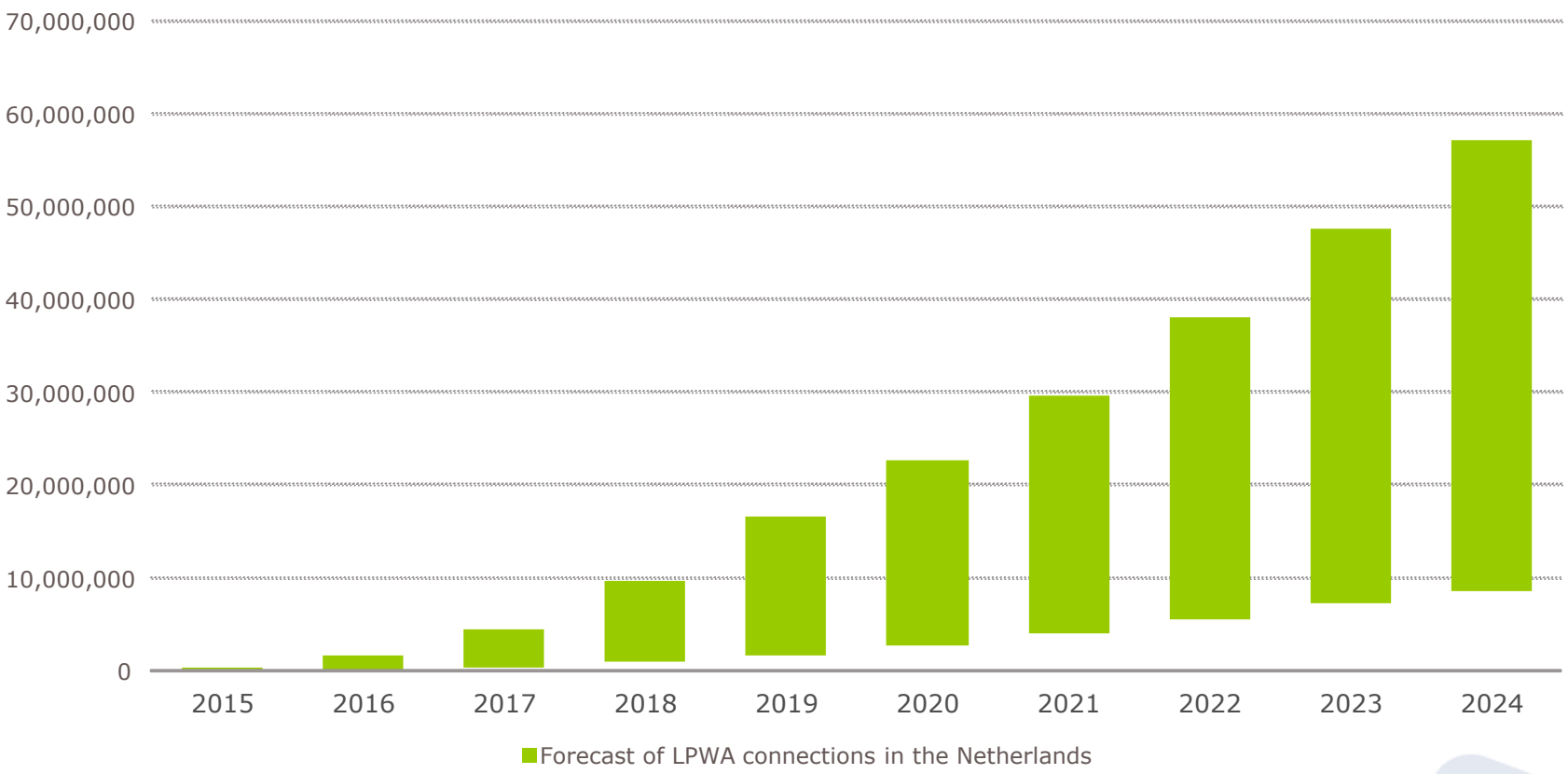
LPWA devices in the Netherlands



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LPWA IoT applications

Smart cities

Consumers

Logistics

Utilities

Agriculture

Smart buildings

Industry

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LPWA IoT applications

Smartphone-controlled household appliances (#households in NL)

Smoke detectors
2,530,000

Smart thermostats
2,690,000

Security cameras
2,000,000

Distance controlled lighting
2,140,000

Dishwasher/washing machine
620,000

Baby monitor
580,000

Shutter or blinds
1,050,000

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Which issues will be caused by wireless IoT applications (re. spectrum usage), and what are possible solutions?

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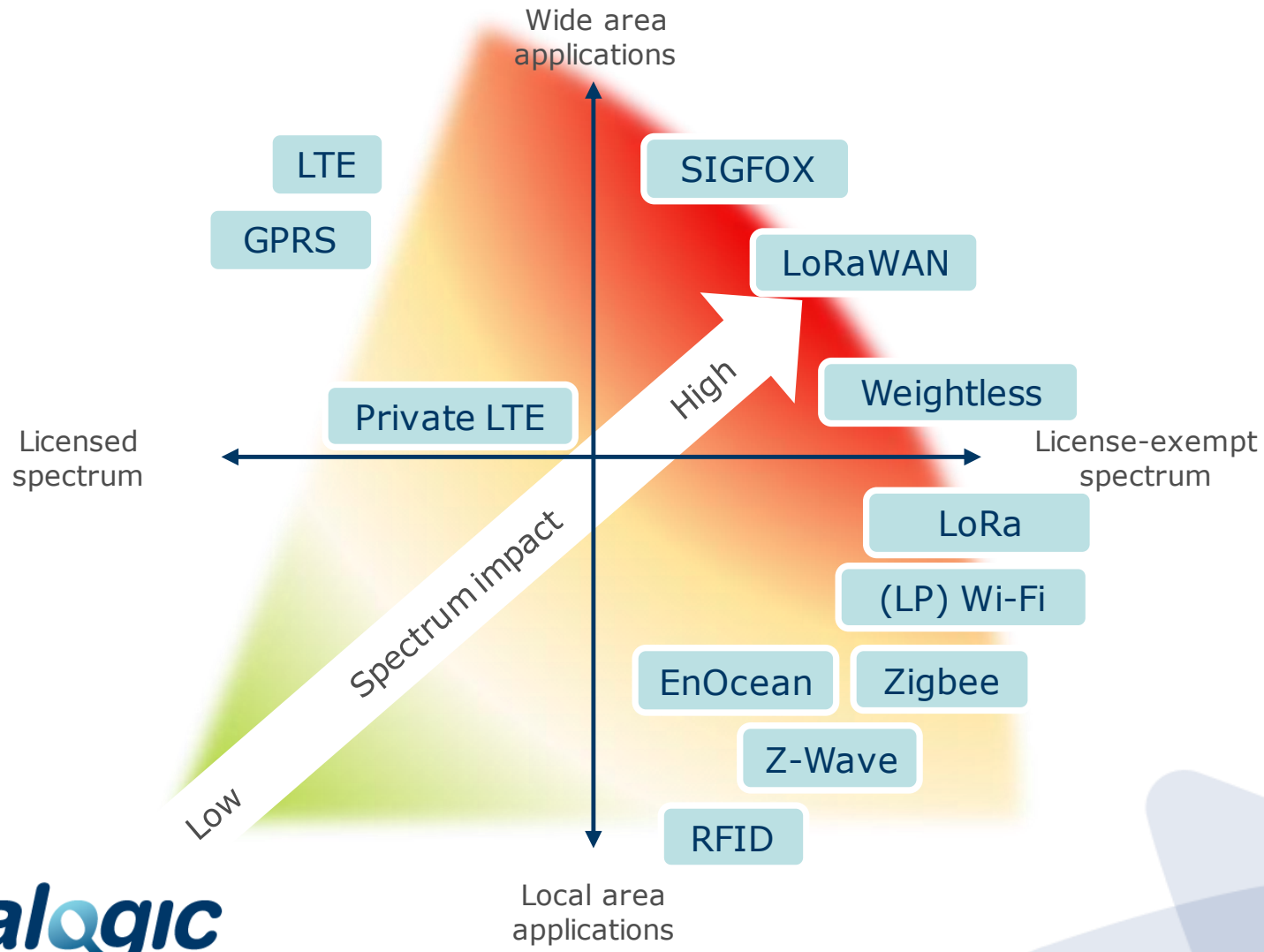
Technologies for wireless IoT



Many short-range IoT applications do not necessarily need to use spectrum below 1 GHz.

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Unlicensed spectrum

LoRaWAN

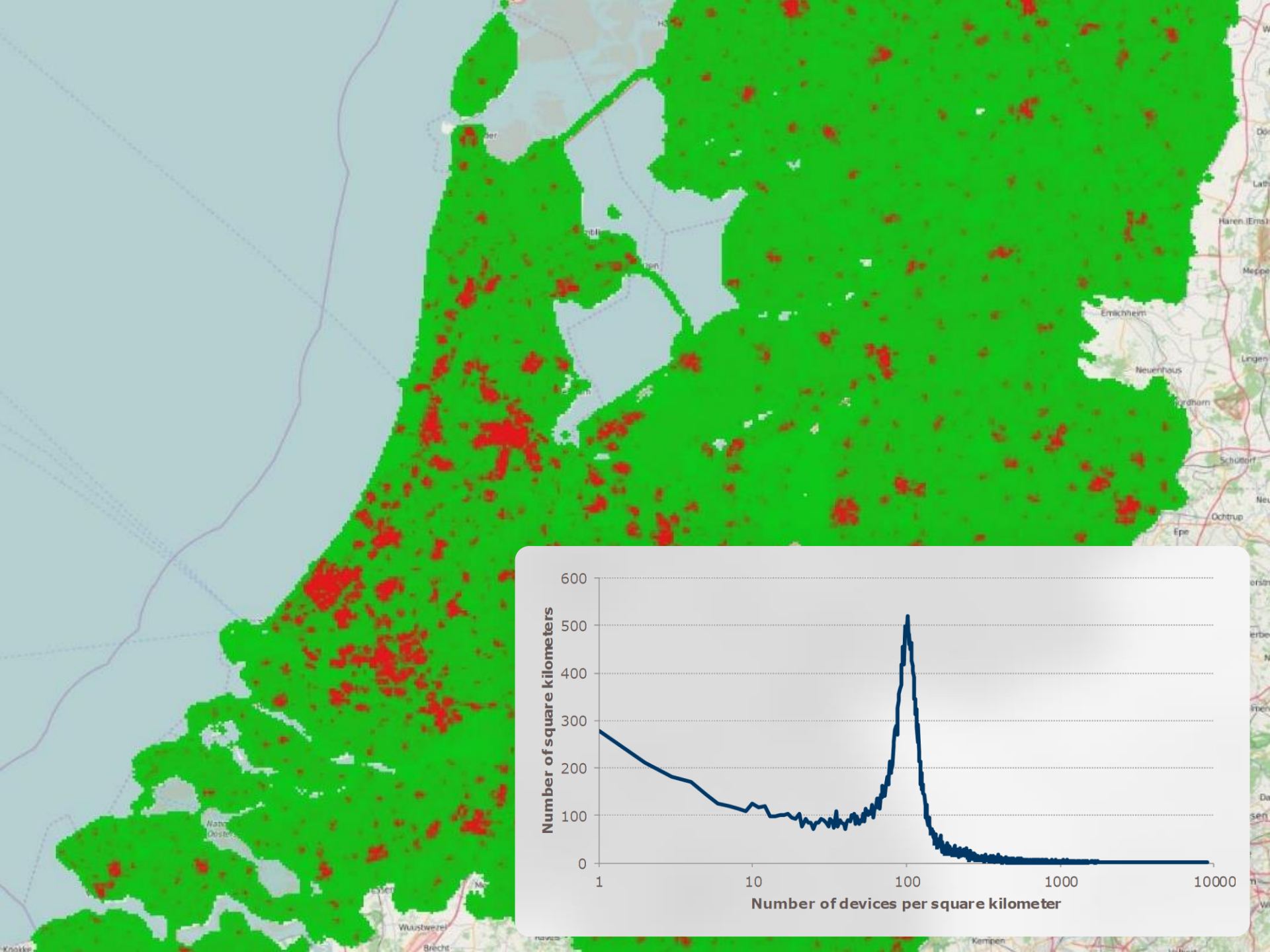
SIGFOX

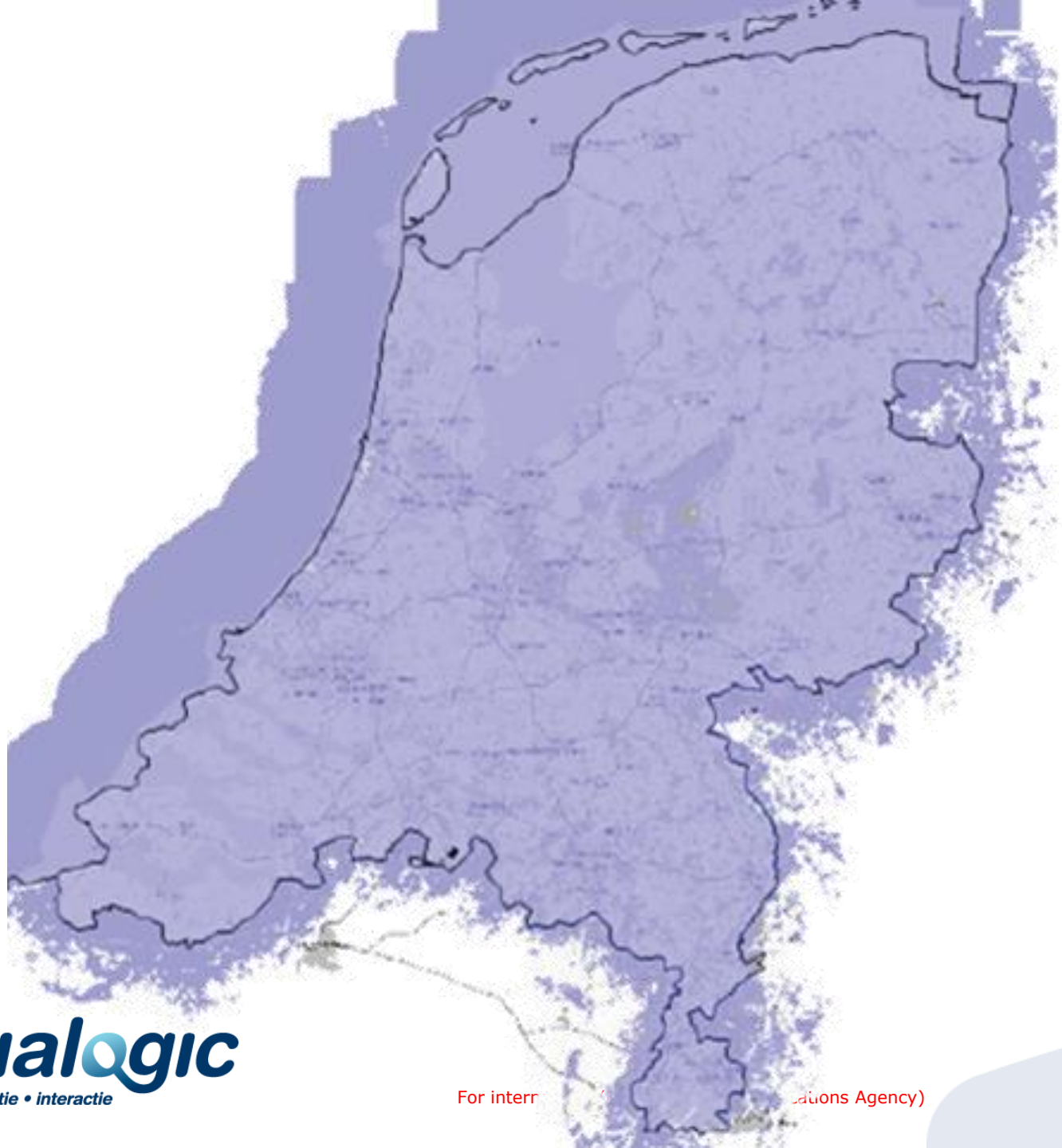
Licensed spectrum

LTE-M

	SIGFOX	LoRa	clean slate cIoT	NB LTE-M Rel. 13	LTE-M Rel. 12/13	EC-GSM Rel. 13	5G (targets)
Range (outdoor) MCL	<13km 160 dB	<11km 157 dB	<15km 164 dB	<15km 164 dB	<11km 156 dB	<15km 164 dB	<15km 164 dB
Spectrum Bandwidth	Unlicensed 900MHz 100Hz	Unlicensed 900MHz <500kHz	Licensed 7-900MHz 200kHz or dedicated	Licensed 7-900MHz 200kHz or shared	Licensed 7-900MHz 1.4 MHz or shared	Licensed 8-900MHz 2.4 MHz or shared	Licensed 7-900MHz shared
Data rate	<100bps	<10 kbps	<50kbps	<150kbps	<1 Mbps	10kbps	<1 Mbps
Battery life	>10 years	>10 years	>10 years	>10 years	>10 years	>10 years	>10 years
Availability	Today	Today	2016	2016	2016	2016	beyond 2020


Legend
Agriculture and environment
Consumers
Industrial
Logistics
Smart Buildings
Smart cities
Utility


600
500
400
300
200
100
0
Number of square kilometers
1
10
100
1000
10000
Number of devices per square kilometer



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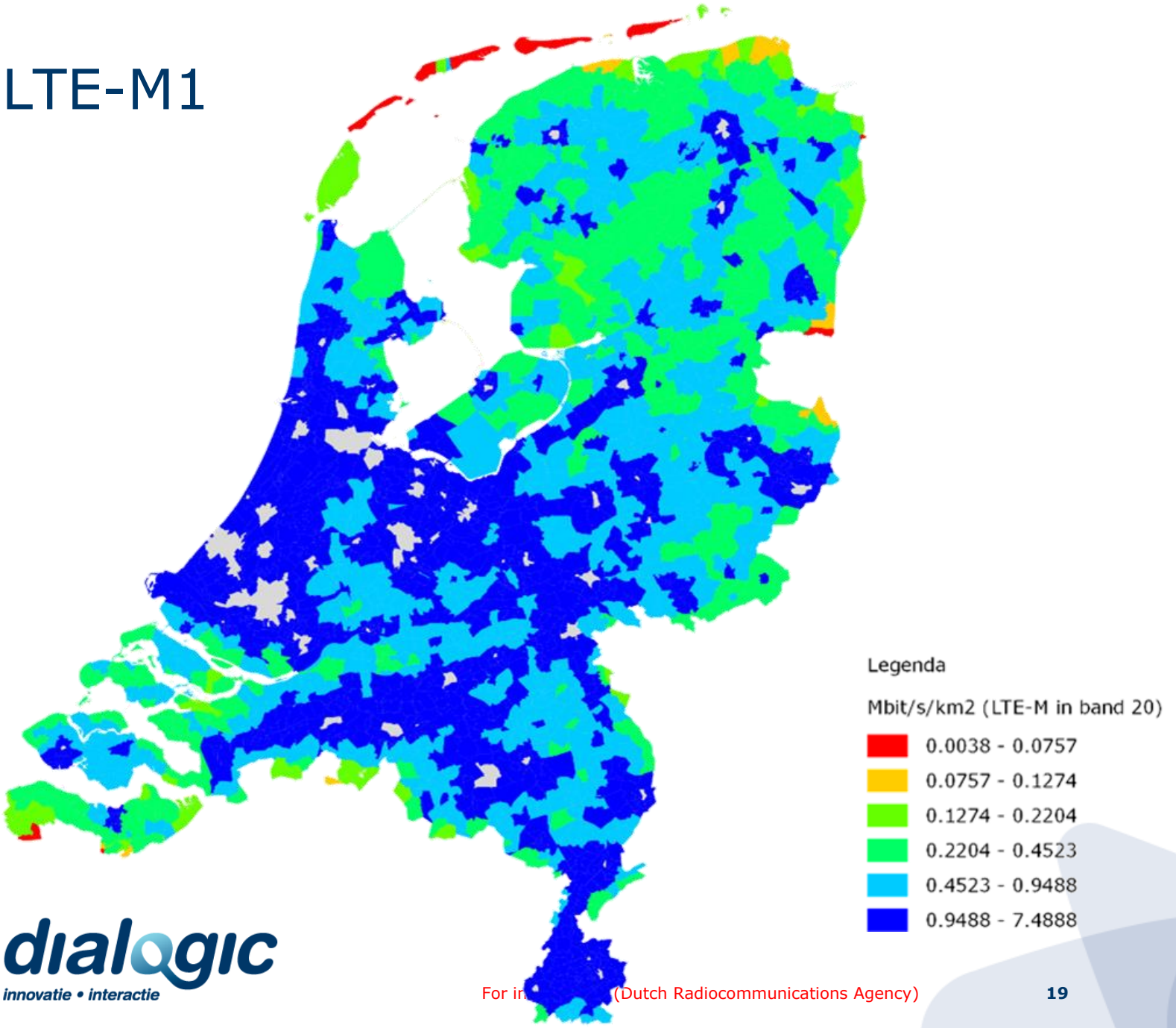
Leeuwarden
Groningen
E22
E232
Alkmaar
E22
Amsterdam
E232
31
E35
E30
Den Haag
Nederland
Arnhem
Rotterdam
E31
43
E311
E25
Eindhoven
Essen
Antwerpen
Düsseldorf
Gent
E19
E25
3
61
Keulen
E313
Brussel
E314
44
Bonn
E40
Aken

LTE-M1



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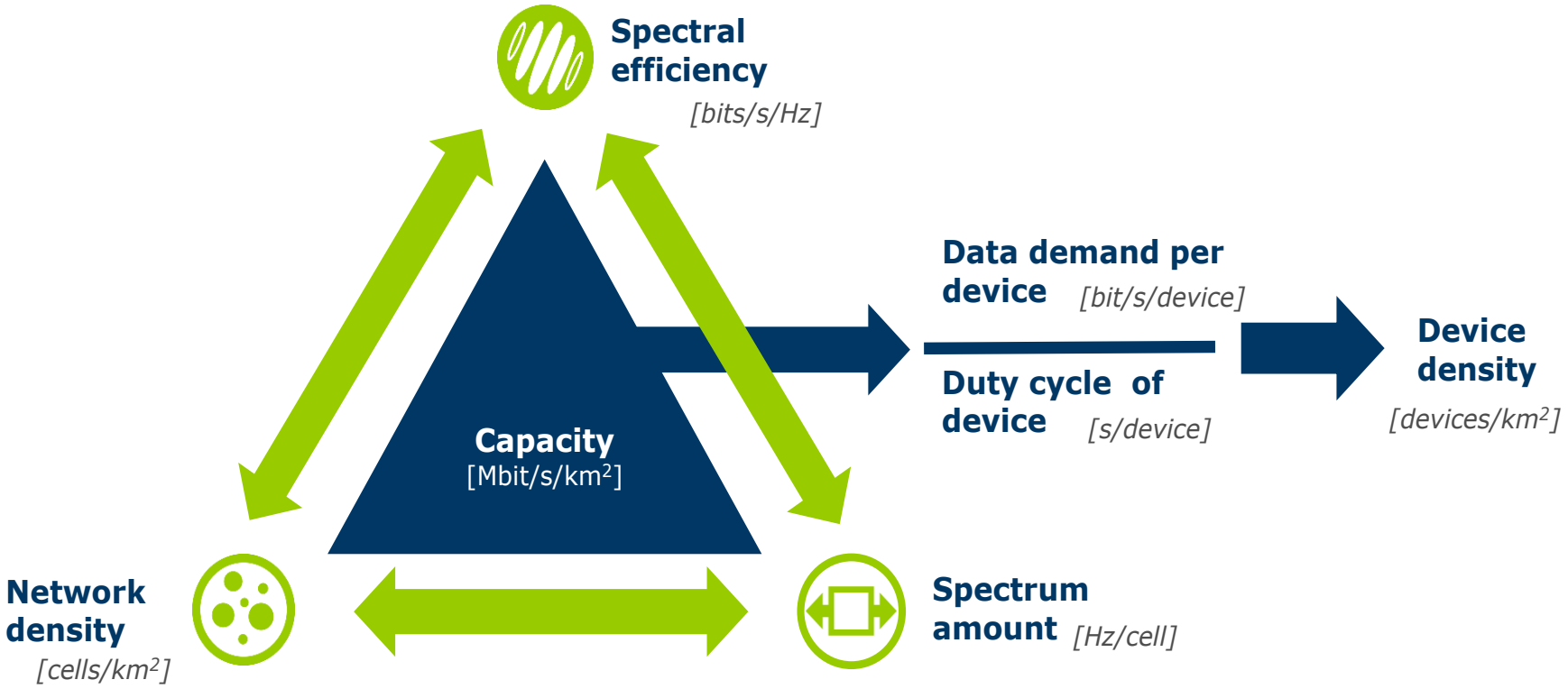
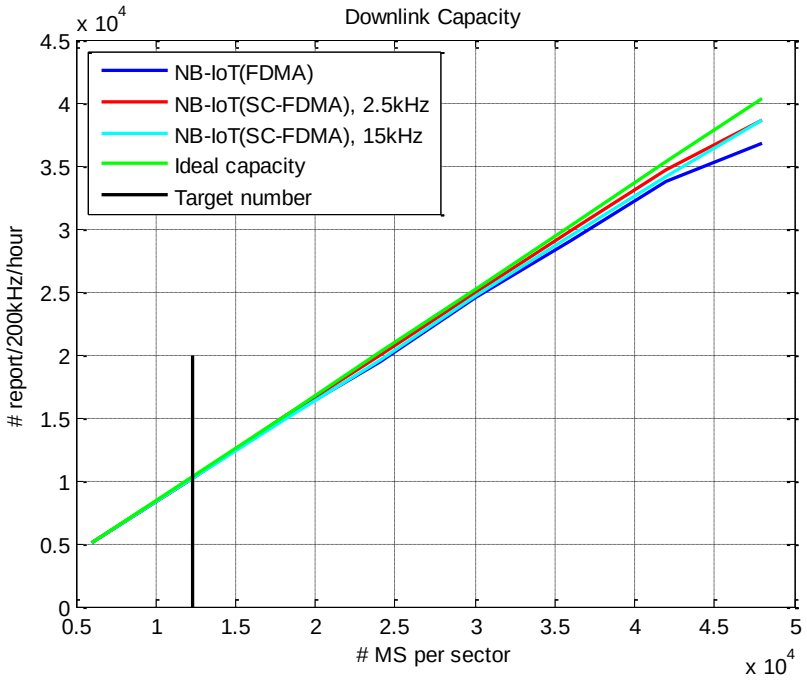
Spectrum impact



Scaling LTE-M

- LTE-M can handle 40k devices per sector *per carrier* easily.
- An LTE-M carrier is 200 kHz wide.
- LTE-M can be embedded in existing LTE carriers, and *dynamically allocated*.
- Note: LTE-M carriers are preferably in the lower frequency bands (800-900 MHz).



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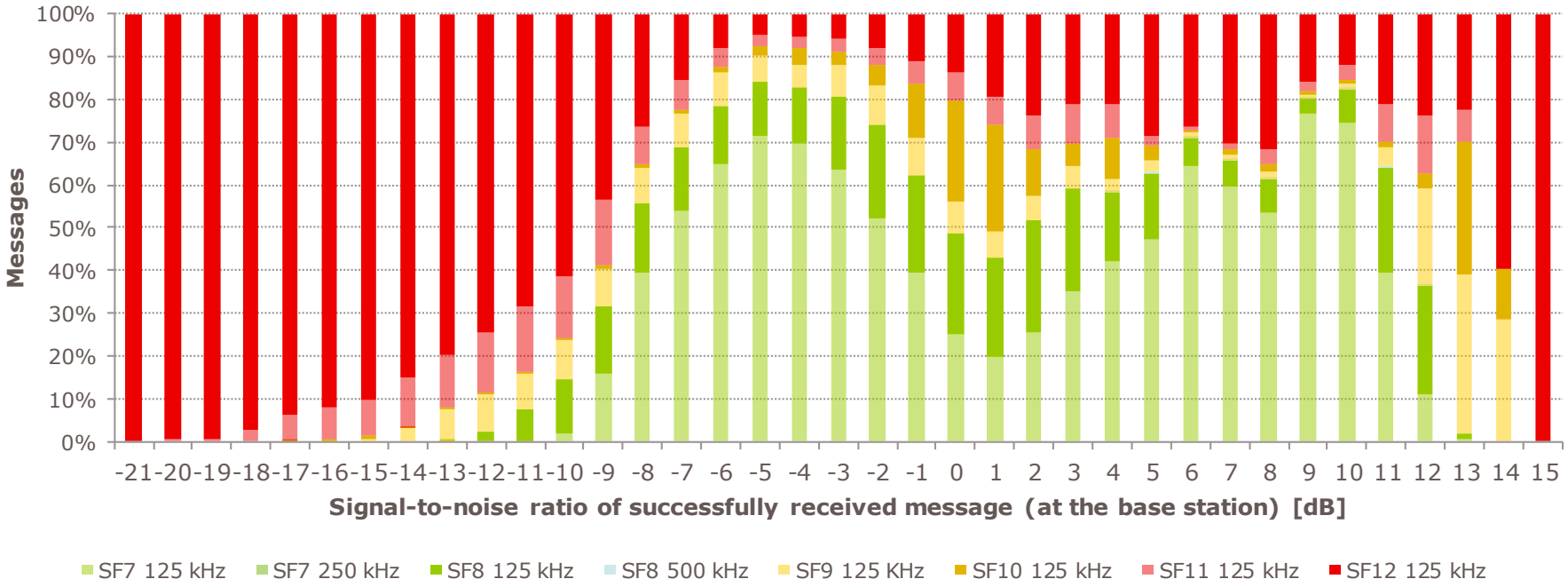
Scaling LPWA IoT in unlicensed bands

- Unlicensed networks cannot perform fine-grained power control, hence cells necessarily overlap (redundantly).
- For the same reason, unlicensed networks cannot control multiple access as tightly.
- Unlicensed networks have to deal with other users of the band (IoT or other).

Spectral efficiency (isolated)



LoRa appears to be unable to select the most efficient modulation type given a certain signal strength. LTE can do this much better (and benefits from dynamic spectrum sharing with existing LTE).

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Scaling unlicensed LPWA = densification

- Because of imperfect power control, LPWA networks in unlicensed bands must reduce the number of devices *per cell*.
- Adding base stations increases overlap, but (in the most pessimistic scenario) doesn't reduce device concentration.
- Base stations need to also reduce power to reduce overlap and devices/cell.

Total device volume	Maximum number of devices per cell			
	20,000	30,000	40,000	50,000
1 million	3.2%	0.8%	0.2%	0.0%
2 million	27.2%	8.5%	3.2%	1.0%
3 million	68.7%	27.2%	12.4%	5.8%
4 million	89.5%	54.5%	27.2%	15.3%
5 million	95.5%	79.4%	46.9%	27.2%
6 million	97.5%	89.5%	68.7%	42.5%
7 million	98.3%	94.1%	82.9%	60.9%
8 million	98.8%	96.2%	89.5%	75.8%

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We expect that the currently available spectrum is *sufficient* to handle the expected connectivity demand for wireless IoT:

1. There is massive capacity and scaling opportunities for LTE-M

2. For unlicensed networks, there ample capacity at shorter ranges. Densification can be done flexibly as networks require little planning.

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Interferentie

	LPWA IoT	
	Licensed	Unlicensed
Same LPWA IoT network		
Different LPWA IoT network, same technology		
Different LPWA IoT network, different technology		
Other legitimate application		
Other illegitimate application		

The use of unlicensed spectrum for mission-critical communications presents a risk with respect to televulnerability.

The usage of different kinds of technology for LPWA IoT in unlicensed spectrum leads to additional interference and suboptimal usage of the spectrum.

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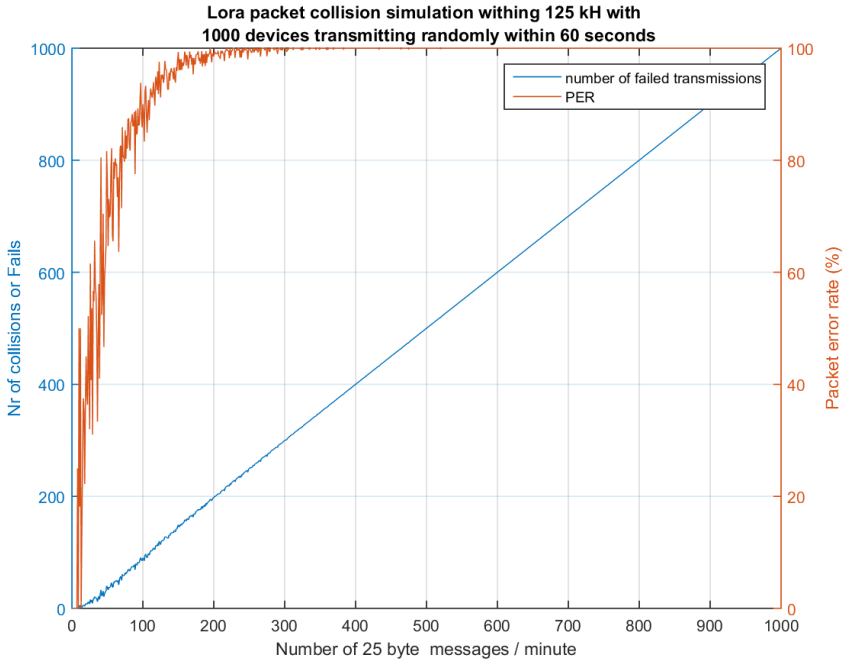
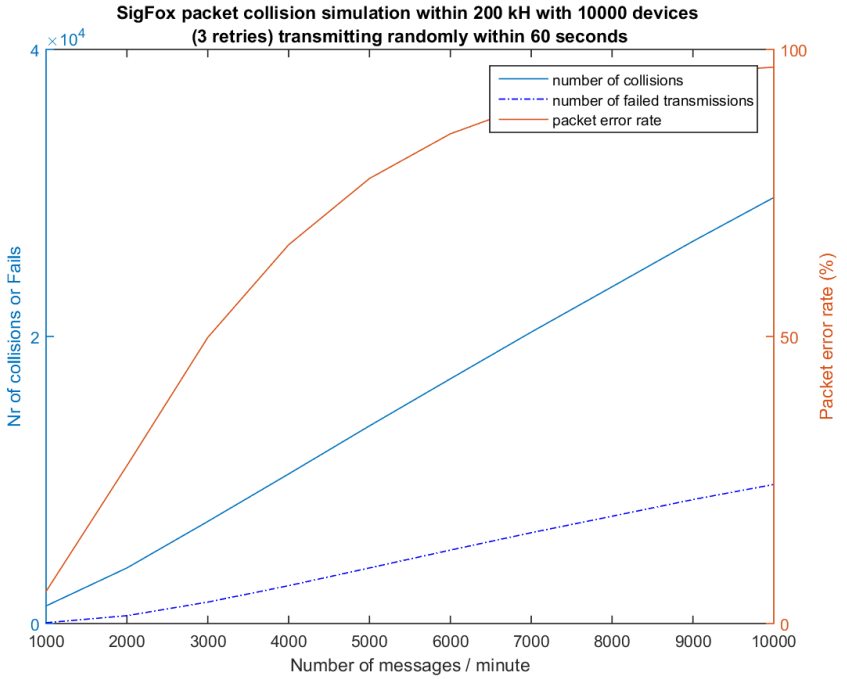
Resilience of LoRa and SIGFOX





SIGFOX appears to be slightly more resilient than LoRa with respect to interference, primarily because of 3-6 retransmission scheme.

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Interference: other users

- LPWA IoT in unlicensed bands will interfere with (and experience interference from) existing users.
- Primarily RFID and long-transmitting applications (wireless microphones) may cause issues.
- LPWA IoT base stations have a long range downlink, increases impact.
- Short range device near a base station can cause interference that blocks the whole cell.

Interference: among LPWA IoT

	Victim Systems	
Aggressor Systems	UNB	Spread Spectrum
Own network UNB	Re-transmission strategy part of normal operation. Dimensioned to contain clash probability to acceptable levels	N/A
Other network UNB	Increased uplink clashes can be mitigated by using more channels and additional base station processing. Frequency re-planning may be needed to avoid interference.	Difficult to avoid impact of multiple simultaneous interference across wideband carrier. Impact worse on uplink, reducing range with the potential for some nearby interferers to block base station receiver.
Own network Spread spectrum	N/A	Intra-system interference will constrain (uplink) capacity – particularly with imperfect power control. Splitting users into 'near' and 'far' groups on different frequency channels can reduce impact but may not be feasible for mobile/nomadic end-points.
Other network Spread spectrum	Difficult to avoid impact of multiple simultaneous interference across all overlapped UNB carriers. Impact worse on uplink, reducing range with the potential for some nearby interferers to block base station receiver. Co-located base stations employing power control would mitigate interference – making deployment co-ordinated.	Difficult to avoid impact of multiple simultaneous interference across all overlapped carriers. Impact worse on uplink, reducing range with the potential for some nearby interferers to block base station receiver. Co-located base stations employing power control would mitigate interference – making deployment co-ordinated.

What are obstacles affecting the oversight and regulatory enforcement of wireless IoT applications?

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Problems resulting from interference with and between LPWA IoT transmissions will be primarily local and intermittent.

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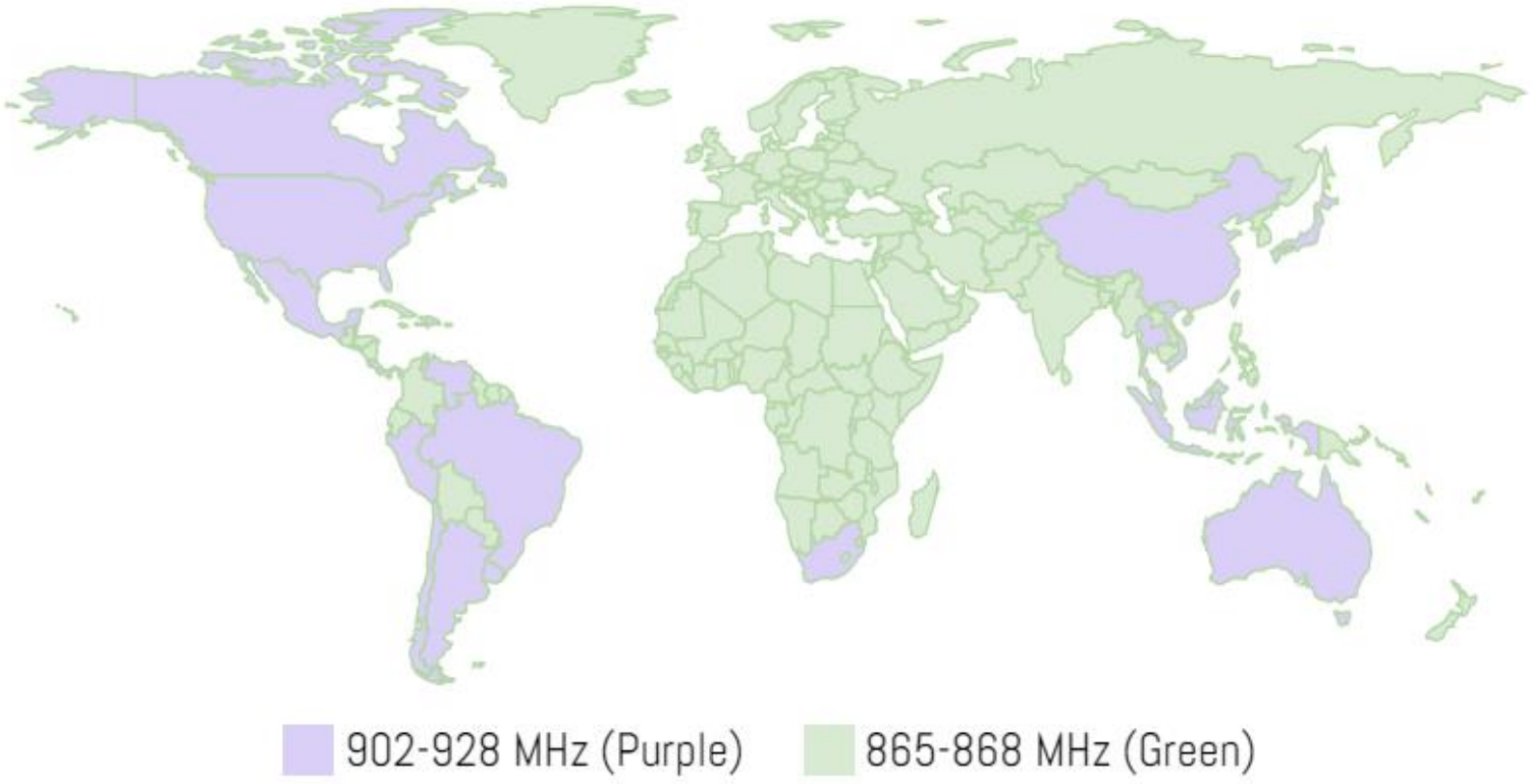
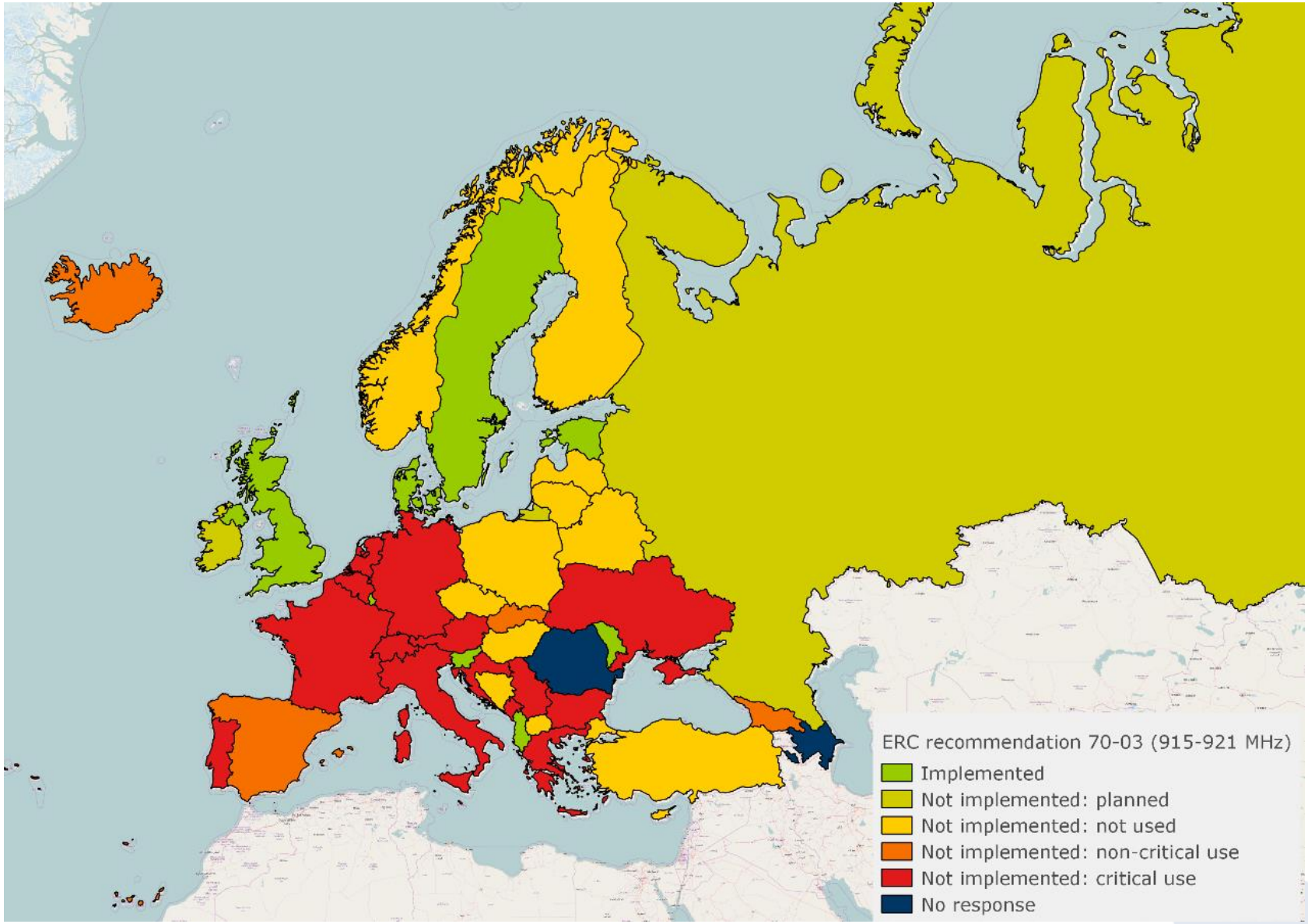
We expect interference from devices that are imported from countries outside of Europe, especially in the 902-928 MHz band.


902-928 MHz (Purple)
865-868 MHz (Green)



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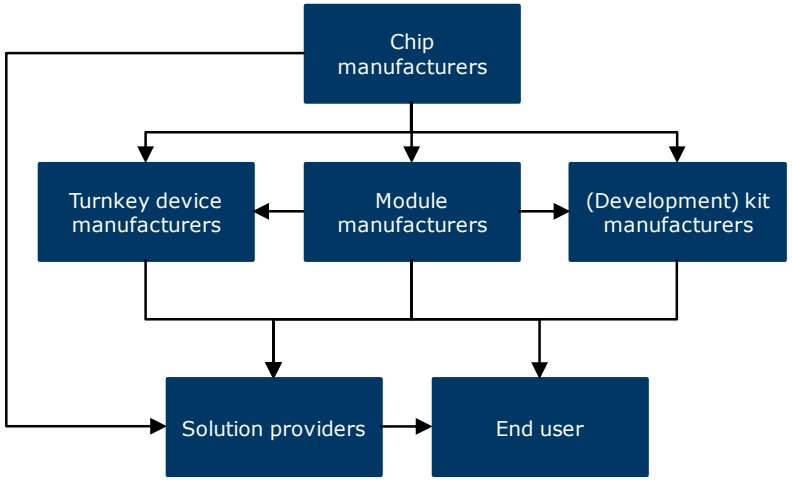
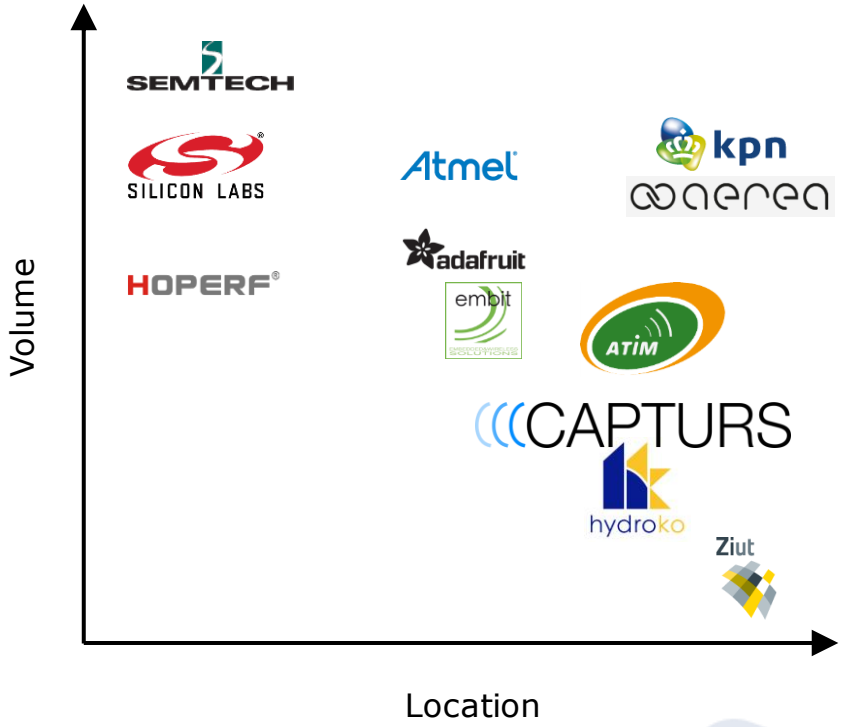
Monitoring trade flows is very difficult, due to high variety of end-user ‘things’
(can be dishwashers, etc.).

Trade flows: trade-off between location and volume





Traditional monitoring instruments can, to a limited extent, be reconfigured for monitoring wireless IoT spectrum usage.

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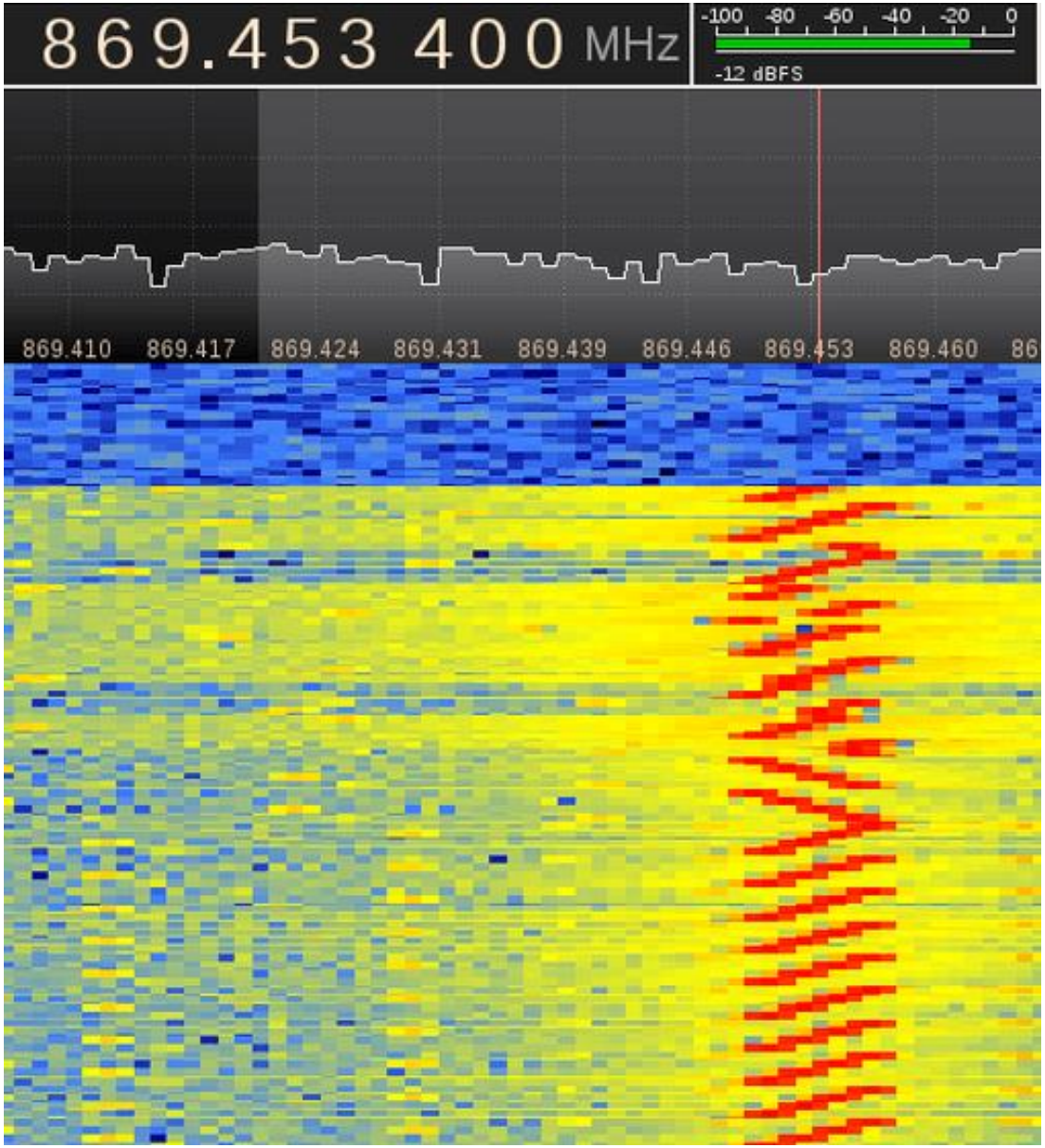

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Spectrum monitoring

New and old tools combined:

		National measurement network	Mobile measurement nodes	IoT network operator data	IoT measurement nodes
Wide/metro area		√		√	
Local/personal area			√		√
Resolution					
1	Spectrum utilization by IoT	√			√
2	Spectral efficiency of IoT		√	√	
3	Detect generic issues related to IoT	√	√	√	√
4	Troubleshoot specific interference issues		√		

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Instruct operators and user groups to educate (potential) users of IoT LPWA connectivity in unlicensed spectrum about the possible (future) risks regarding availability and reliability.

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Encourage operators of LPWA IoT networks to further densify their network.

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Investigate the possibilities for using data from the IoT network operators for monitoring purposes.

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Do not allocate additional spectrum for LPWA IoT at this point.

Q & A

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