Implications of Roaming in Europe

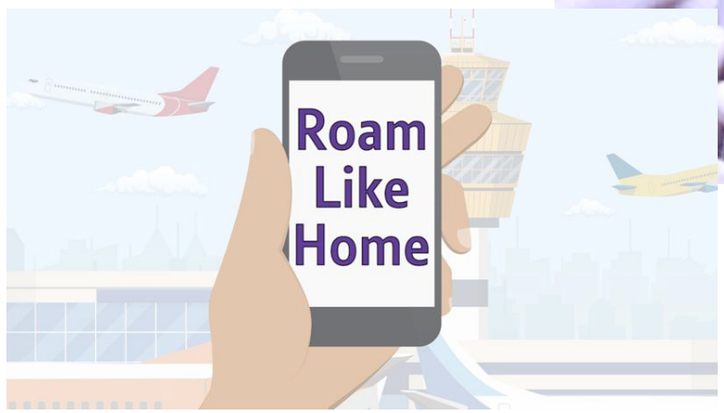
Ali Safari Khatouni (Dalhousie University), A.M. Mandalari (University Carlos III of Madrid),
A. Custura (University of Aberdeen), A. Lutu (Telefonica Research),
O. Alay (Simula Metropolitan), M. Bagnulo (University Carlos III of Madrid),
V. Bajpai (Technische Universität München), A. Brunstrom (Karlstad Universitet),
J. Ott (Technische Universität München), M. Mellia (Politecnico di Torino),
G. Fairhurst (University of Aberdeen)

Outline

- Motivations
- Background
- Experimental setup: MONROE-Roaming
- Measurements:
  - Roaming setup and performance
  - VoIP
  - Content discrimination
- Roaming results
- Experience and conclusion

Outline

- Motivations
- Background
- Experimental setup: MONROE-Roaming
- Measurements:
  - Roaming setup and performance
  - VoIP
  - Content discrimination
- Roaming results
- Experience and conclusion



https://ec.europa.eu/digital-single-market/en/roaming

Why study International Roaming?

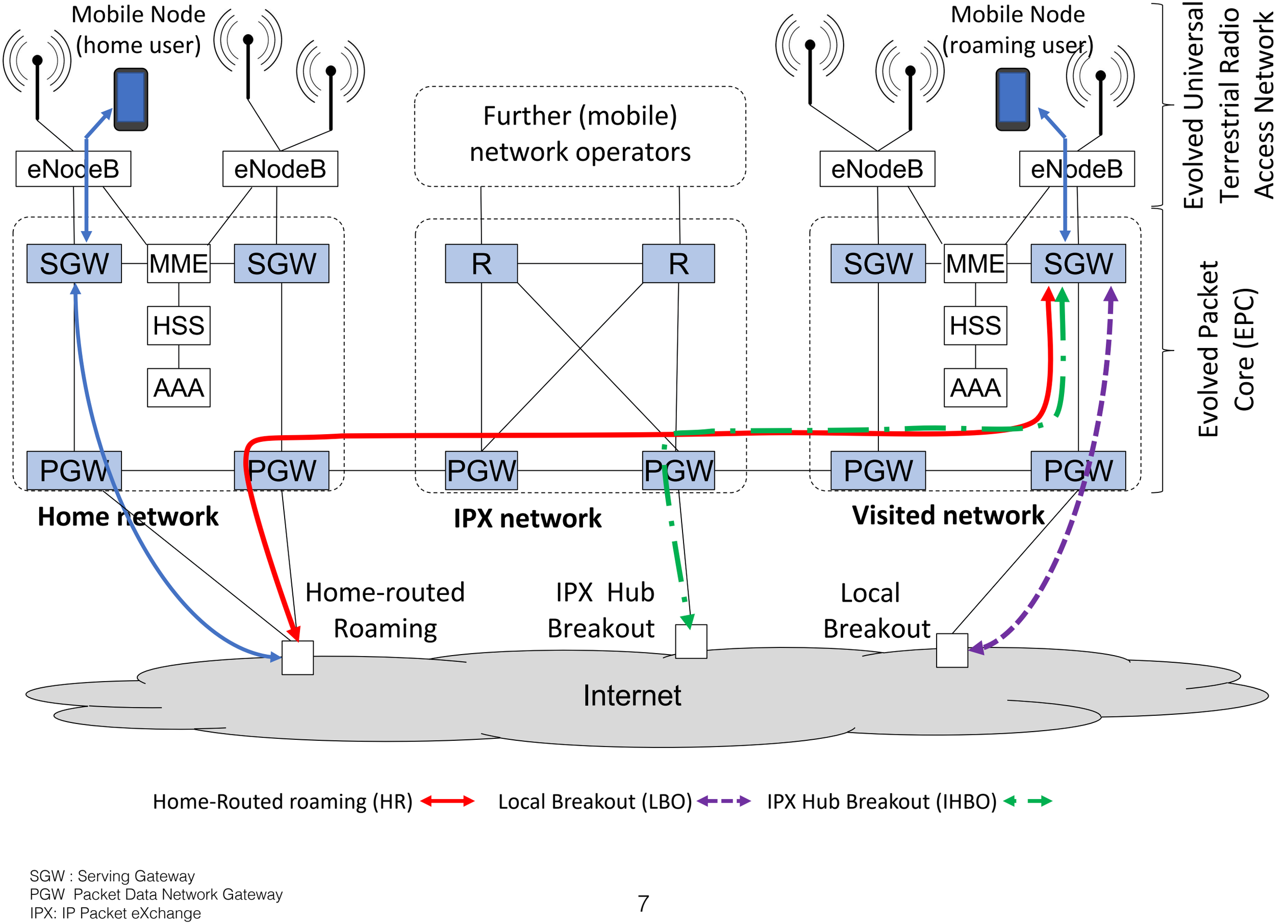
- Understand the roaming ecosystem in Europe after the “Roam like Home” initiative.

- Which technical solutions are actually being deployed and used today?

- What are the implications of roaming on the service experienced by the roaming user?

Outline

- Motivations
- Background
- Experimental setup: MONROE-Roaming
- Measurements:
  - Roaming setup and performance
  - VoIP
  - Content discrimination
- Roaming results
- Experience and conclusion



SGW : Serving Gateway
PGW Packet Data Network Gateway
IPX: IP Packet eXchange

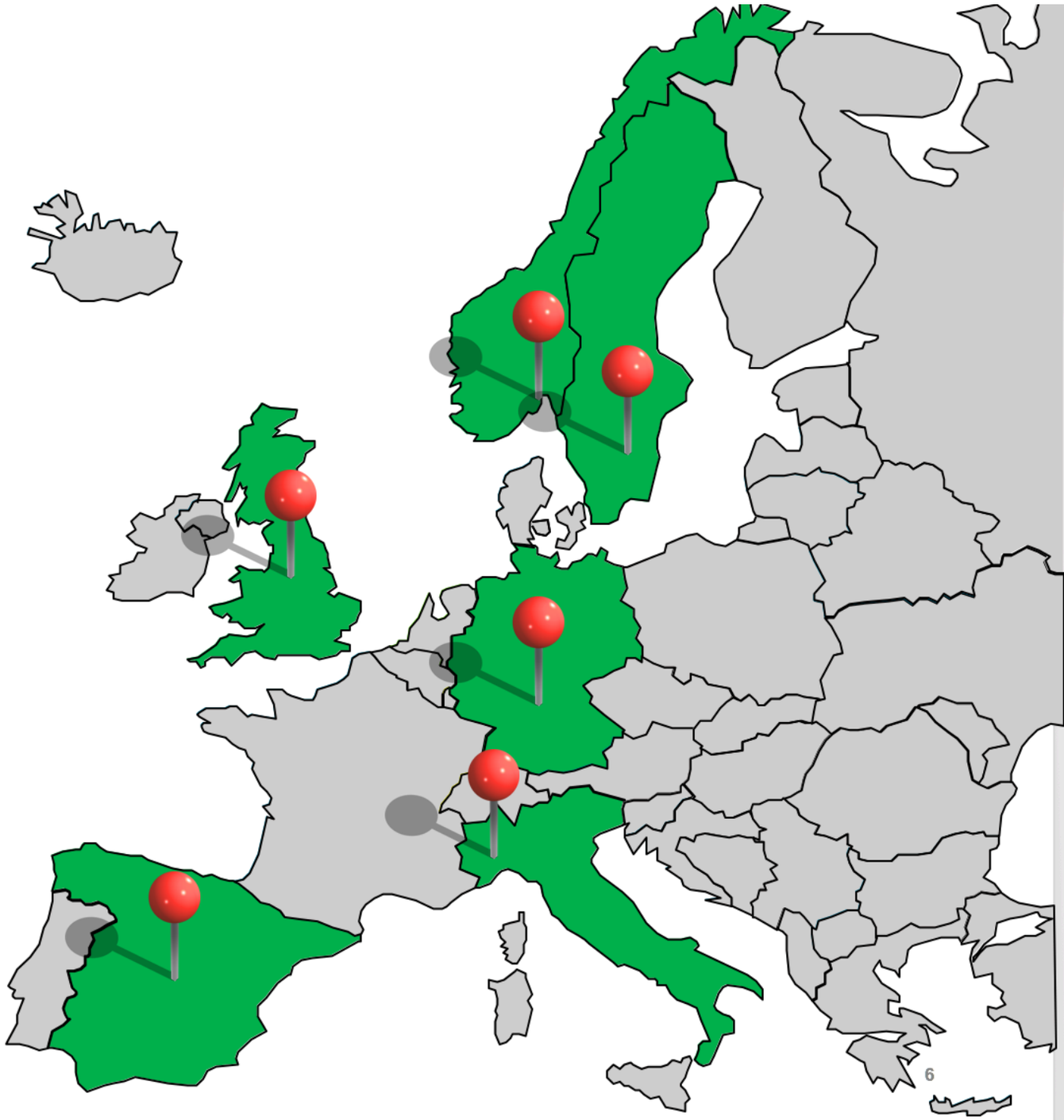
Outline

- Motivations
- Background
- Experimental setup: MONROE-Roaming
- Measurements:
  - Roaming setup and performance
  - VoIP
  - Content discrimination
- Roaming results
- Experience and conclusion

MONROE-Roaming Platform

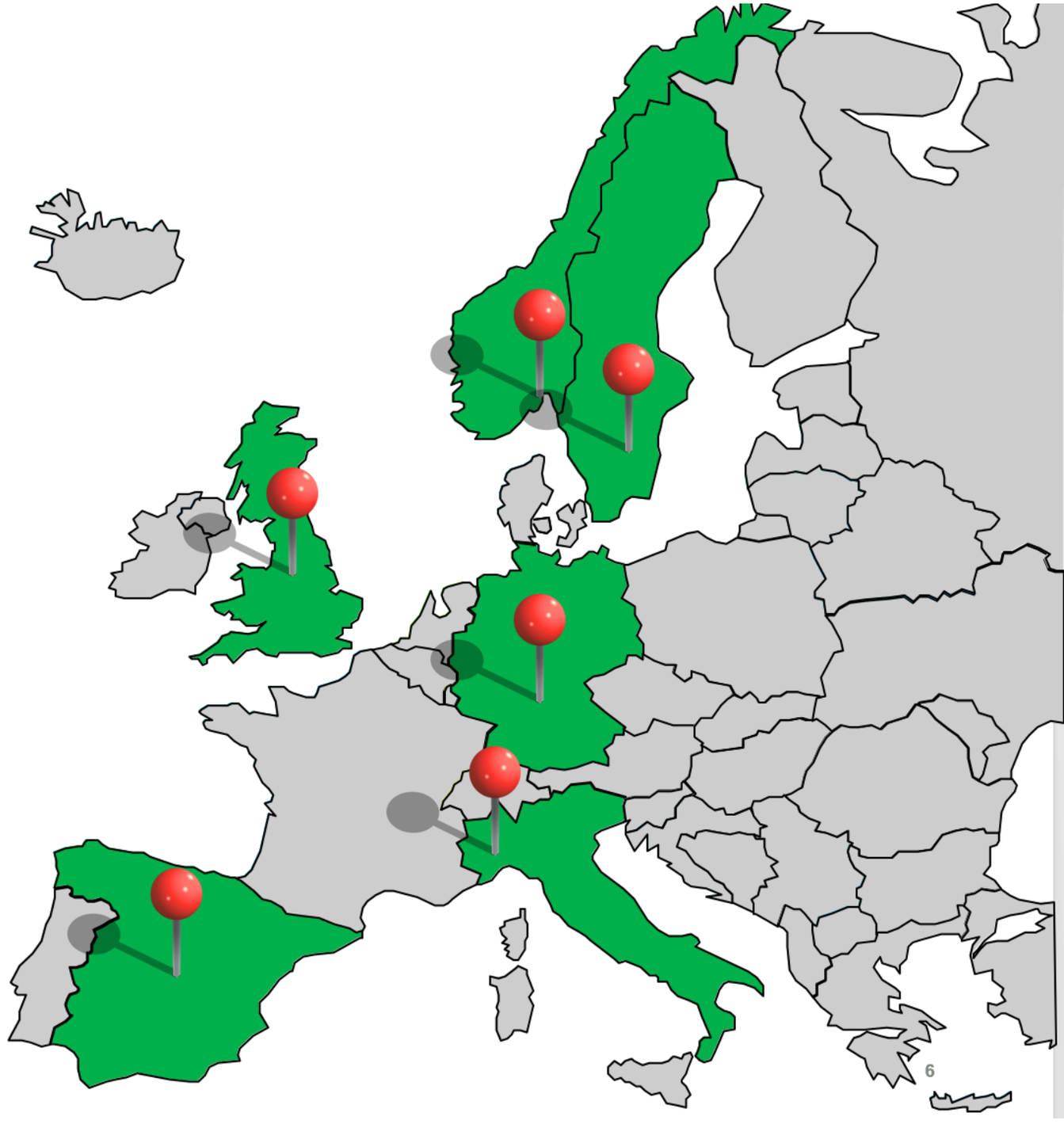
- MONROE-Roaming nodes

Design Aspect	Component
Node Platform	APU2C4
Node Configuration	2xMC7455
Node Hardware	1xAPU + 2xMC7455
Operating System	Debian 9 Stretch
Modem Type	Sierra MC7455 CAT6 miniPCIe modem



MONROE-Roaming Platform

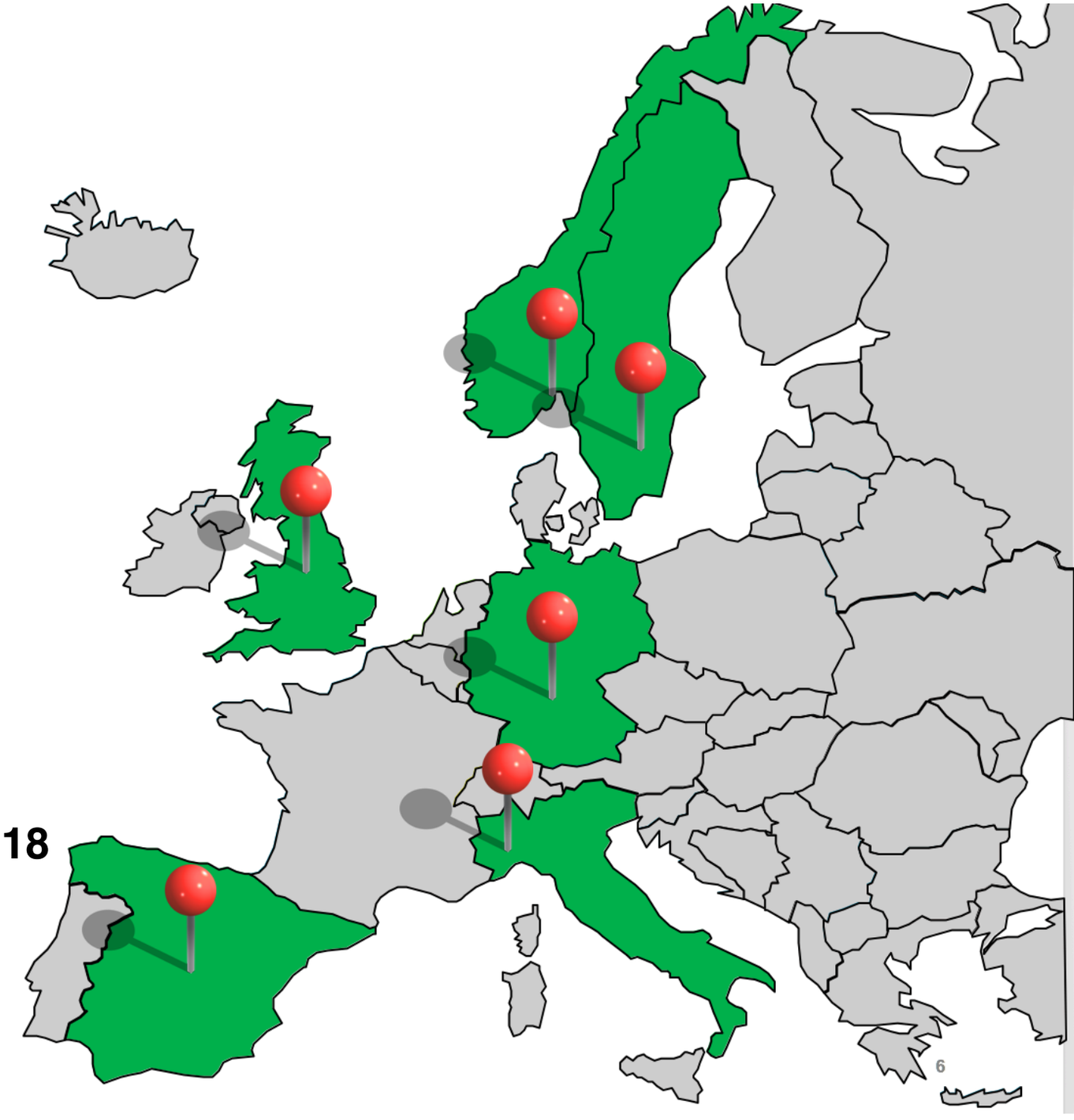
- MONROE-Roaming nodes
- MONROE-Roaming backend
- One measurement server per country
- MONROE-Roaming scheduler



MONROE-Roaming Platform

Mobile Network Operators

NO	Telia NO	Telenor NO	
SE	Telia SE	Telenor SE	3 SE
UK	Vodafone UK	EE	
DE	Vodafone DE	T-Mobile	O2
ES	Vodafone ES	Movistar	Orange
IT	Vodafone IT	TIM	3 IT



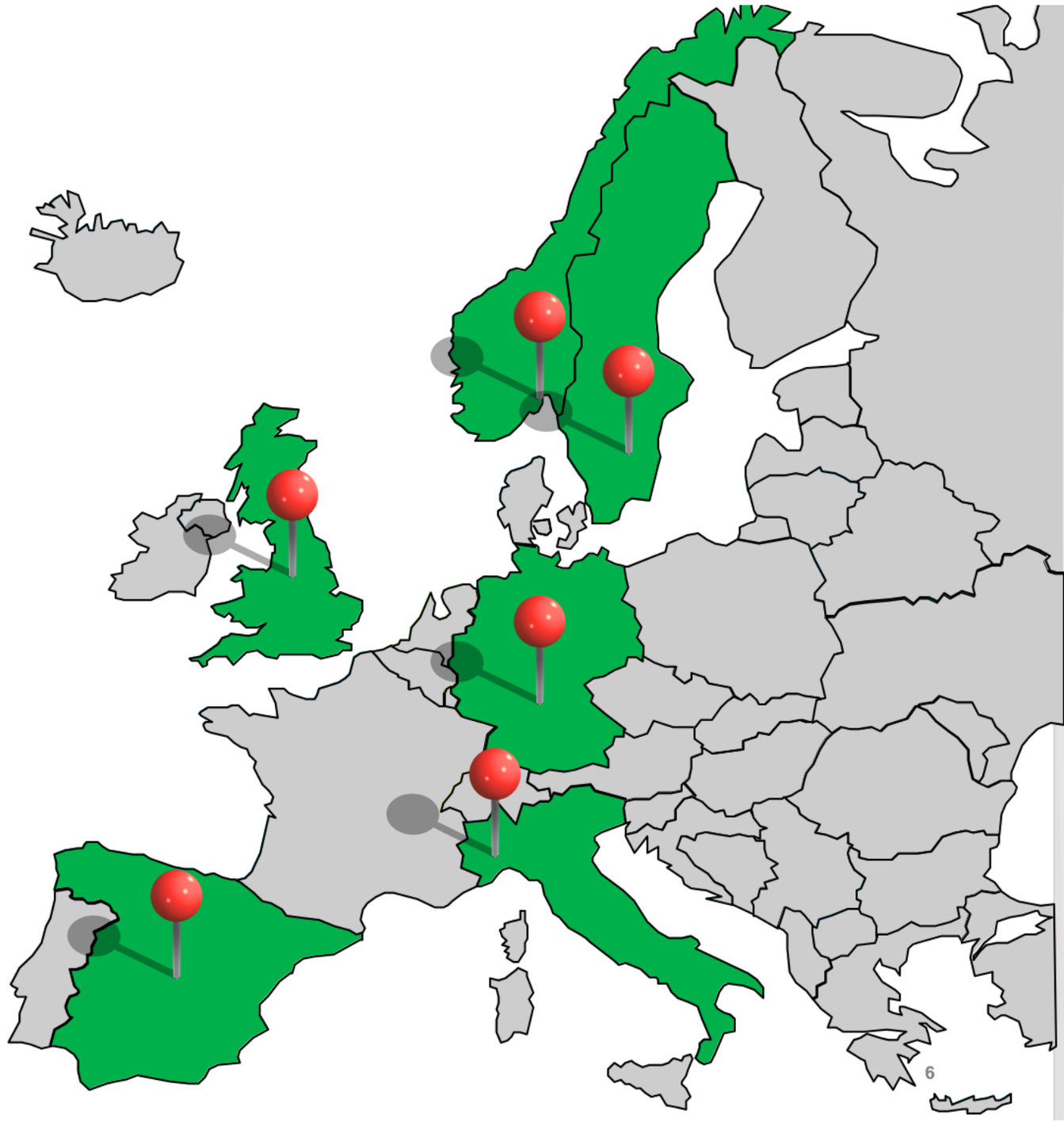
Dataset

- **3 months** of collected traces in **2017** and **2018**
- 12 nodes distributed in **6 countries**
- **16 operators (12 operators in Roaming)**
- More than **20000 experiments**

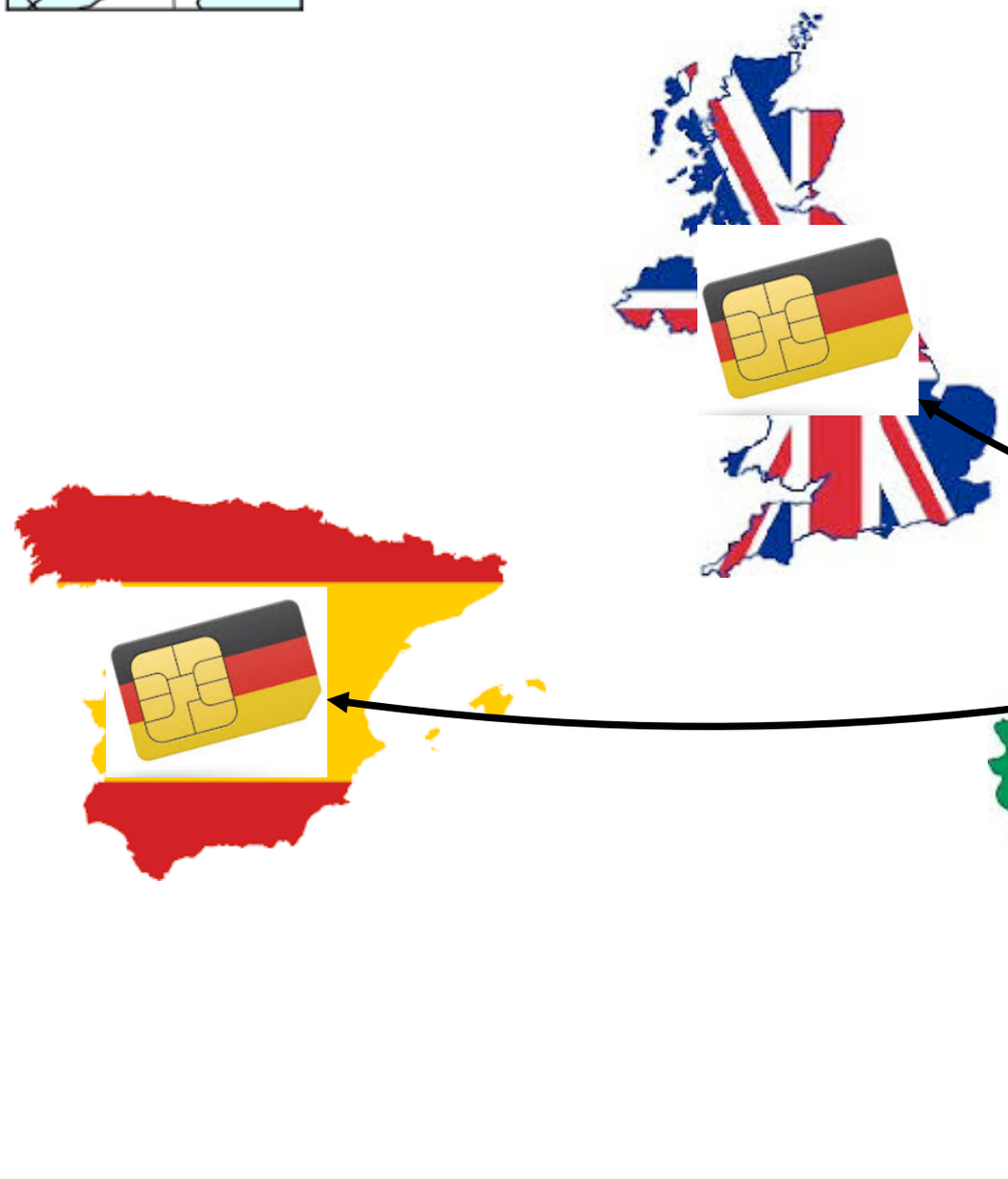
MONROE-Roaming Platform

- Measure one MNO at a time (all nodes have the SAME SIM at the same time).

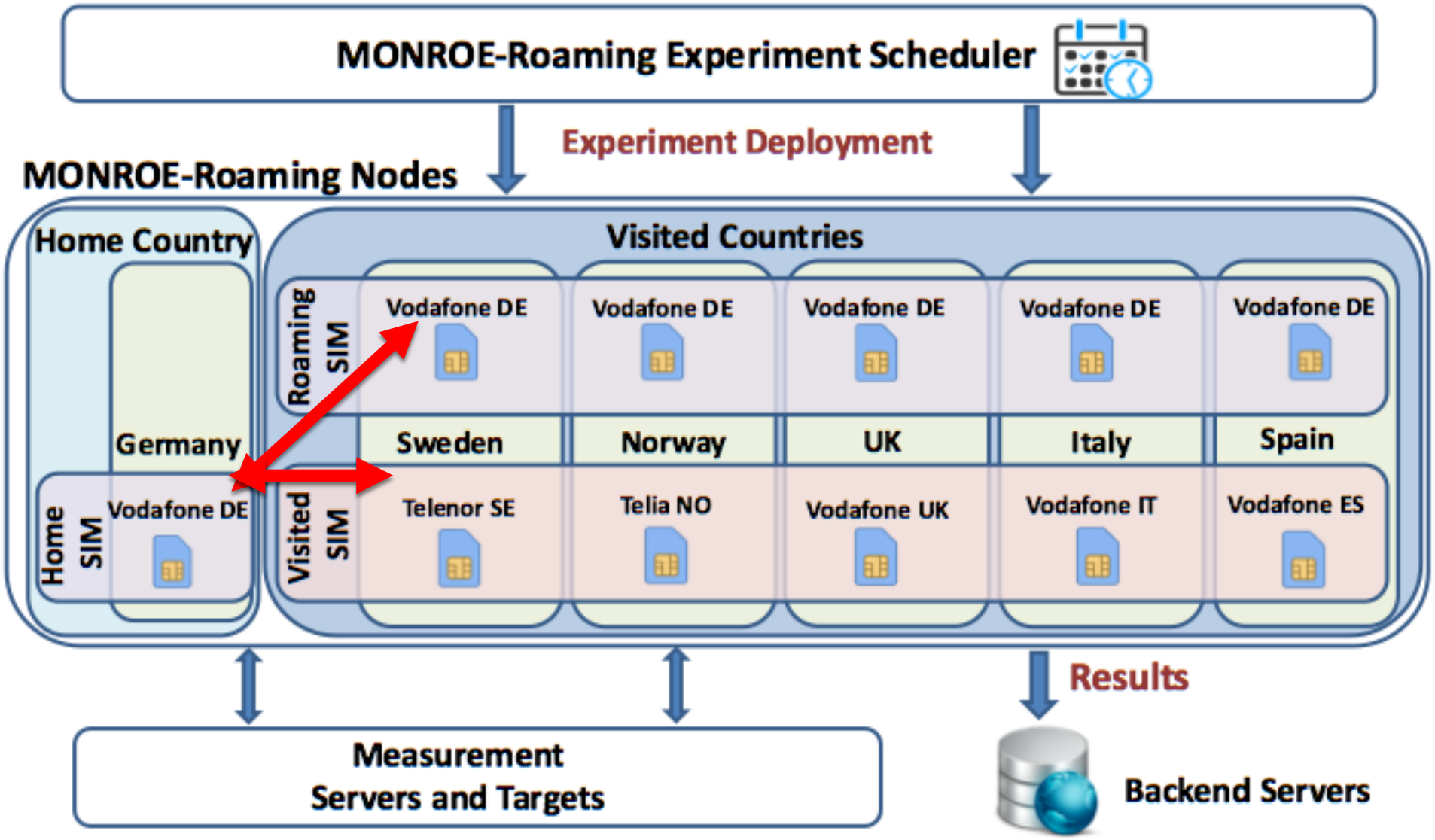
- Measure the visited network natively, where possible.



	MNOs		
NO	Telia NO	Telenor NO	
SE	Telia SE	Telenor SE	3 SE
UK	Vodafone UK	EE	
DE	Vodafone DE	T-Mobile	O2
ES	Vodafone ES	Movistar	Orange
IT	Vodafone IT	TIM	3 IT



Experimental Setup



Outline

- Motivations
- Background
- Experimental setup: MONROE-Roaming
- Measurements:
  - Roaming setup and performance
  - VoIP
  - Content discrimination
- Roaming results
- Experience and conclusion

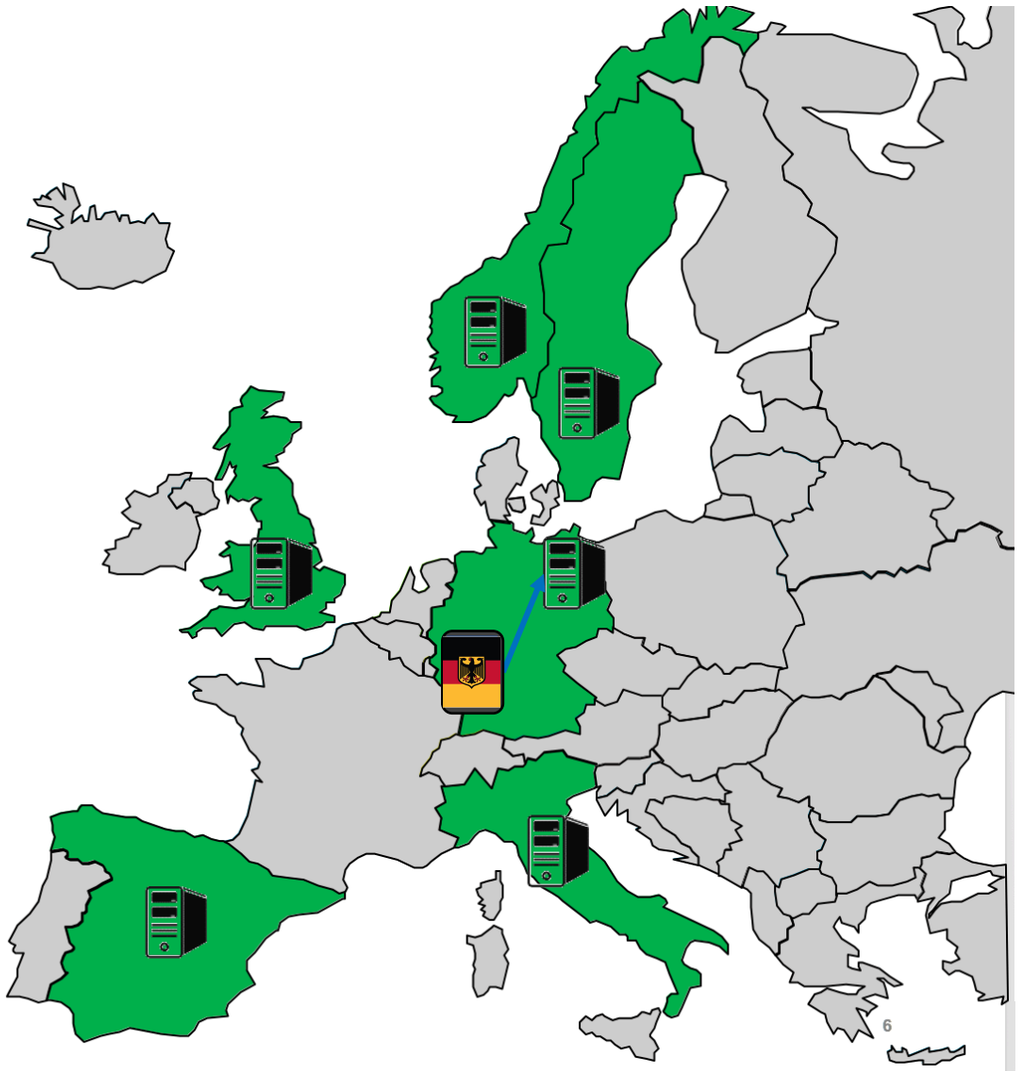
Roaming Setup and Performance: Measurements

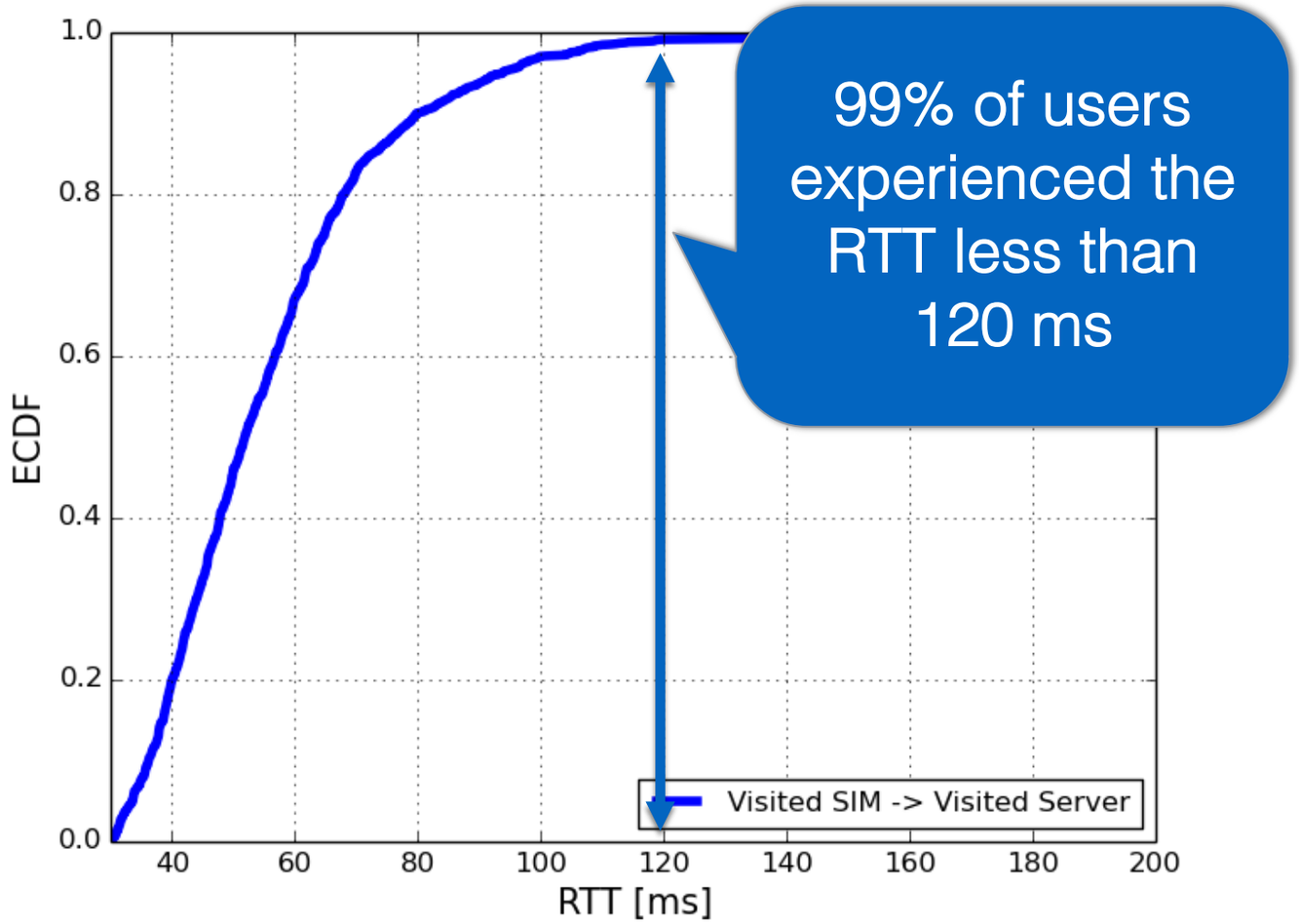
- Radio metadata for tracking the roaming partner
- Traceroute to discover roaming setup
- dig: DNS against third party service providers (ad providers)
- Curl: performance against 10 popular webservers

Outline

- Motivations
- Background
- Experimental setup: MONROE-Roaming
- Measurements:
    - Roaming setup and performance
    - VoIP
    - Content discrimination
- Roaming results
- Experience and conclusion

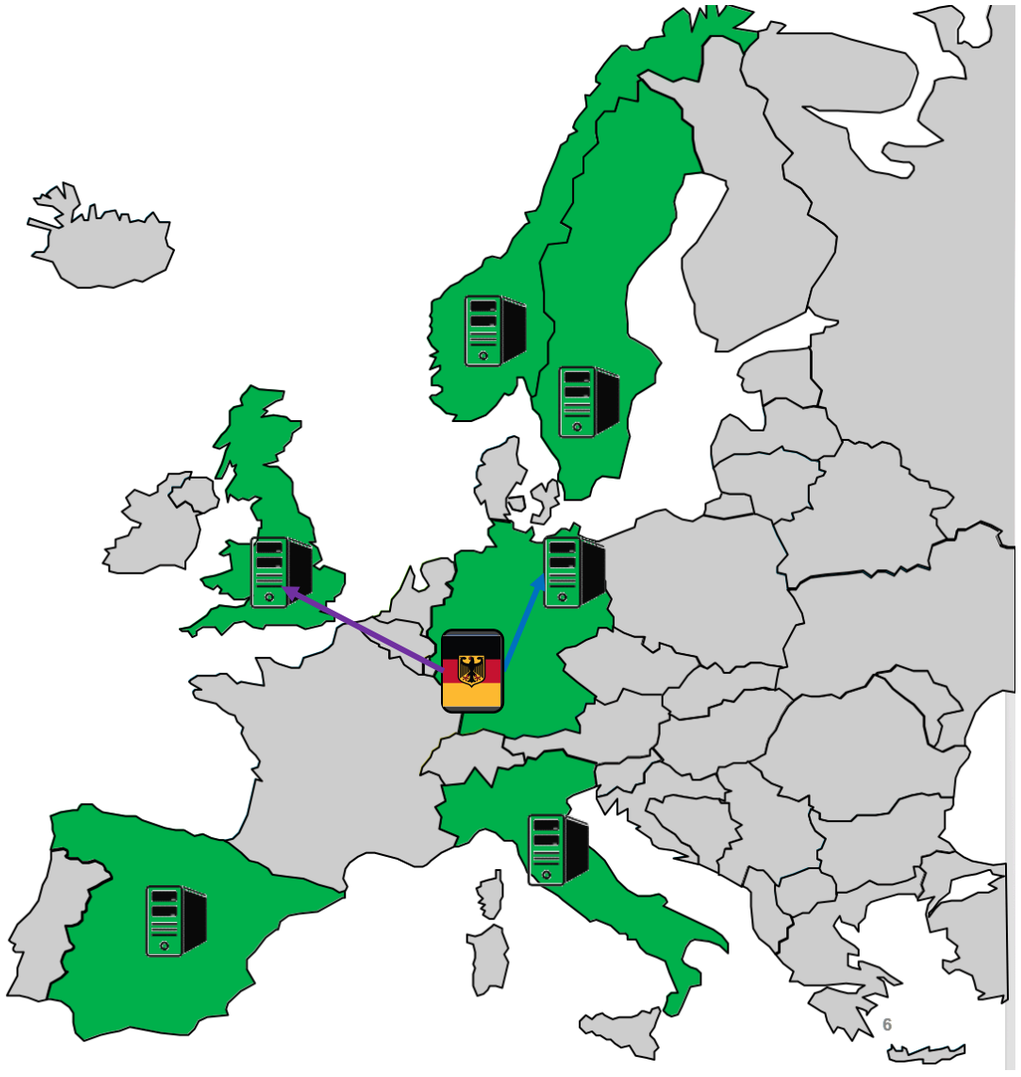
Roaming Setup and Performance: Delay implications

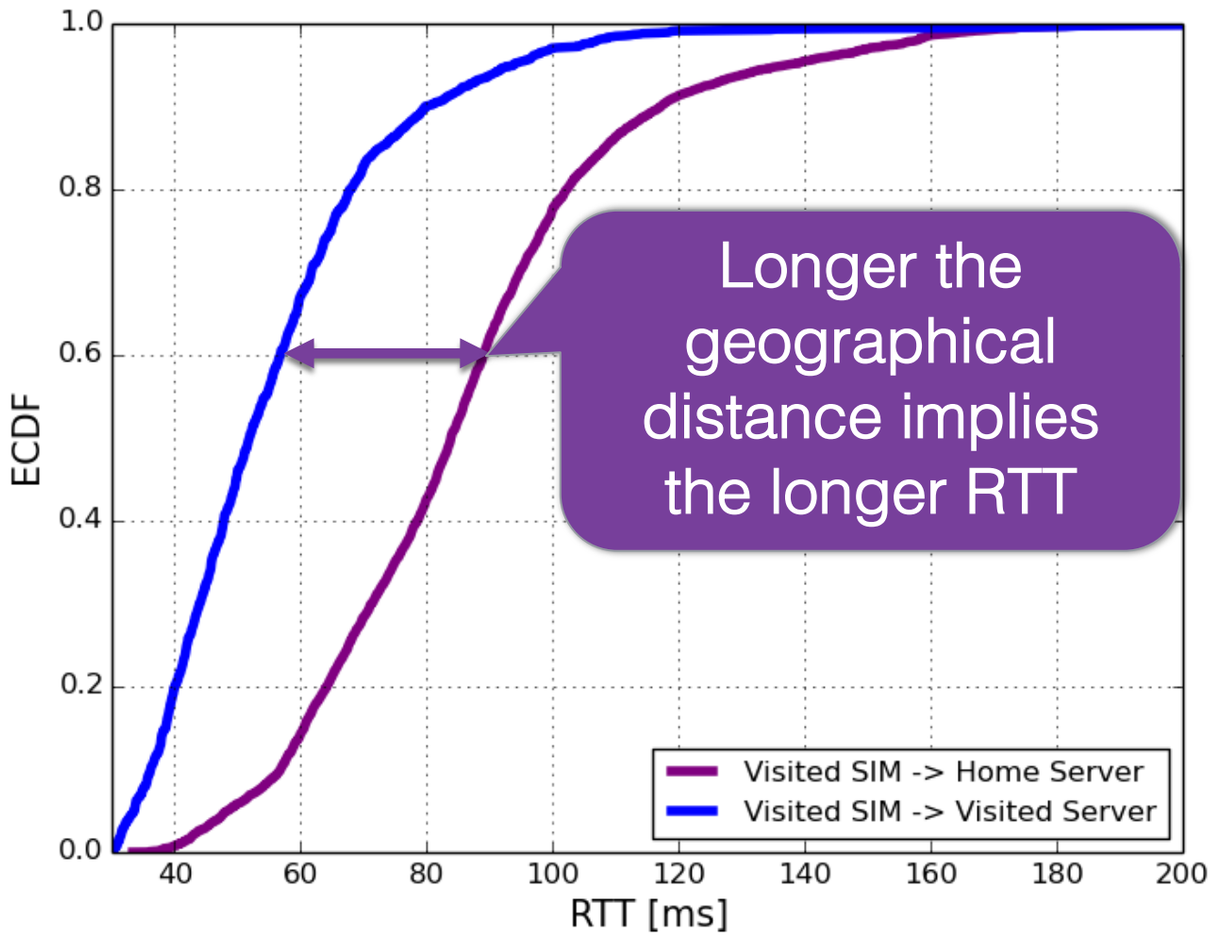




ECDF: Empirical Cumulative Distribution Function

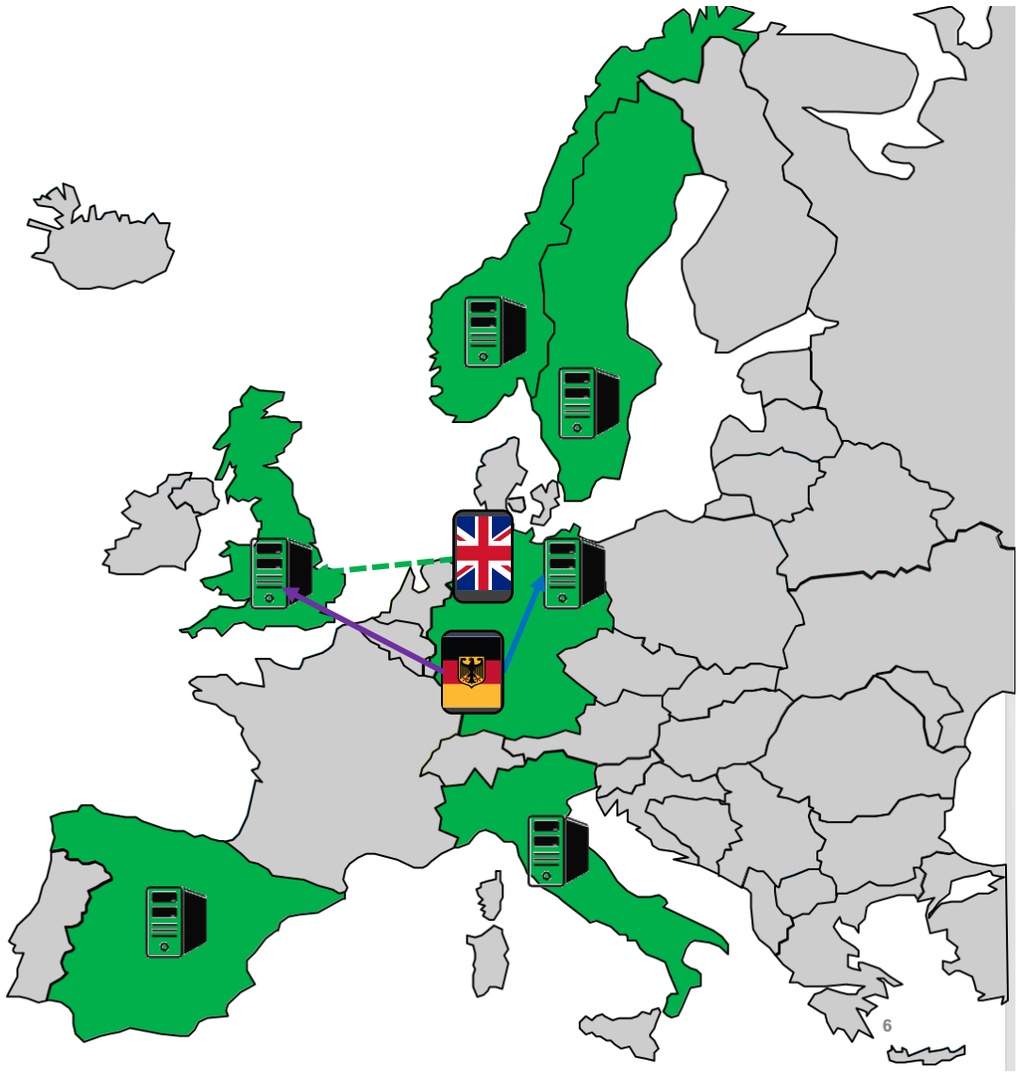
Roaming Setup and Performance: Delay implications

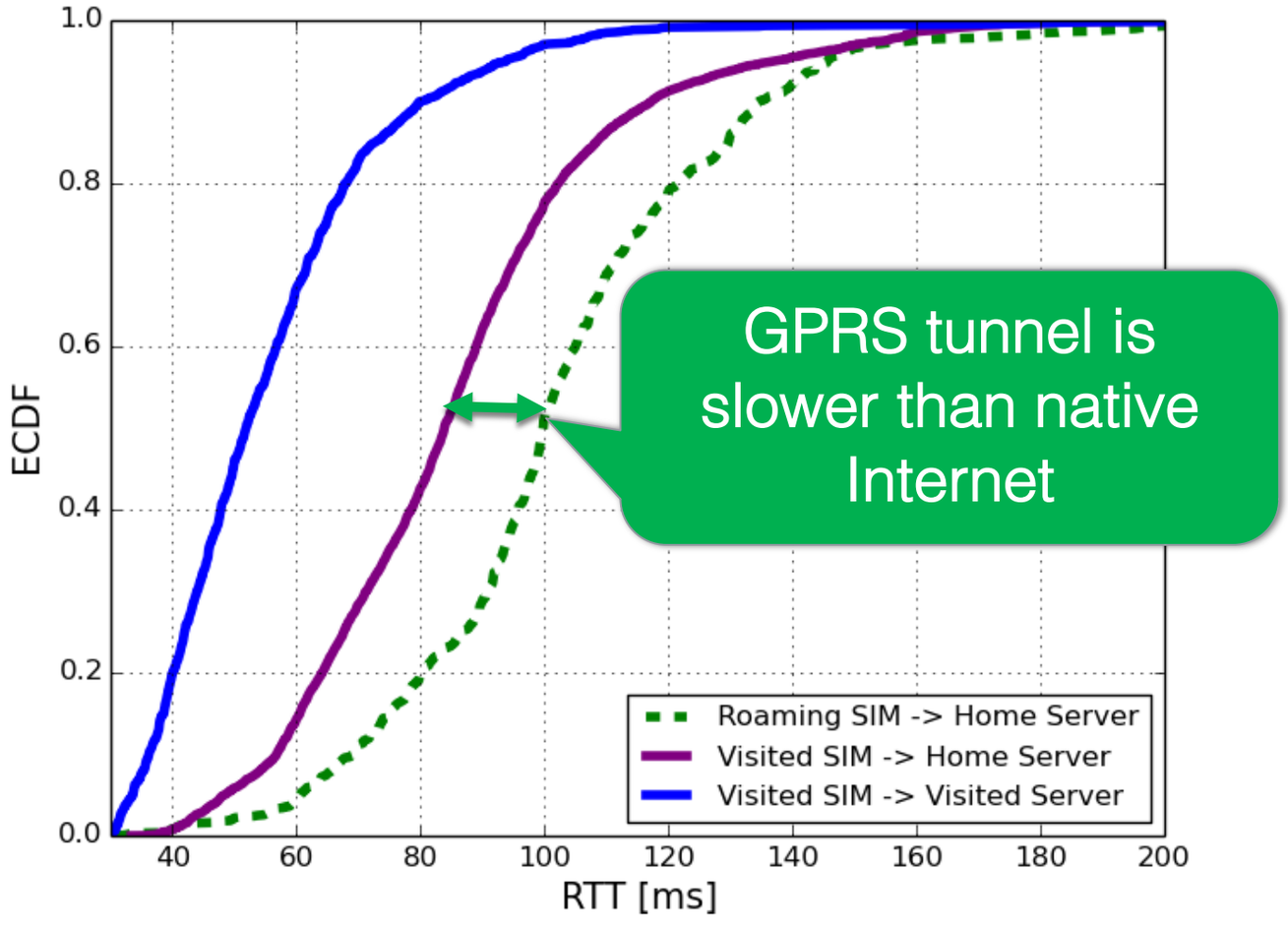




ECDF: Empirical Cumulative Distribution Function

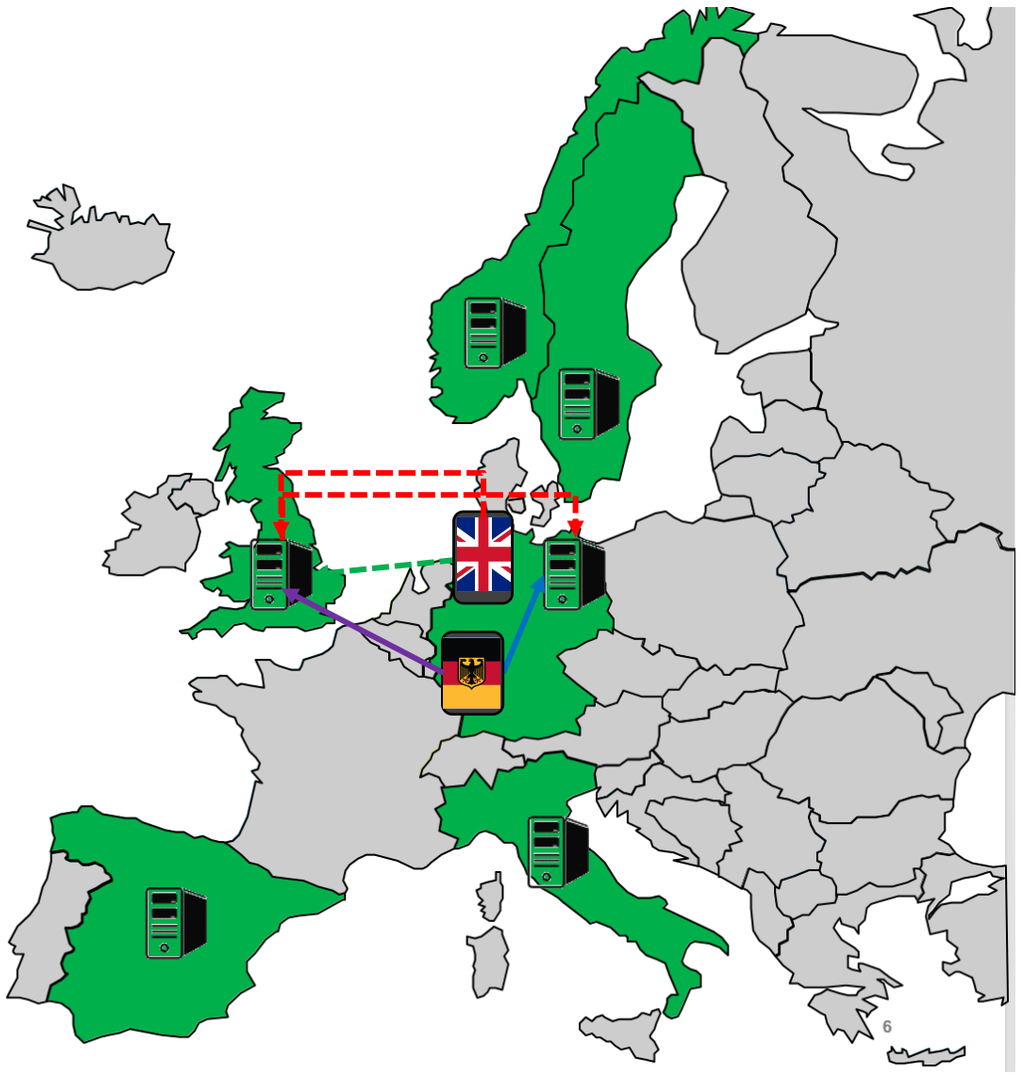
Roaming Setup and Performance: Delay implications

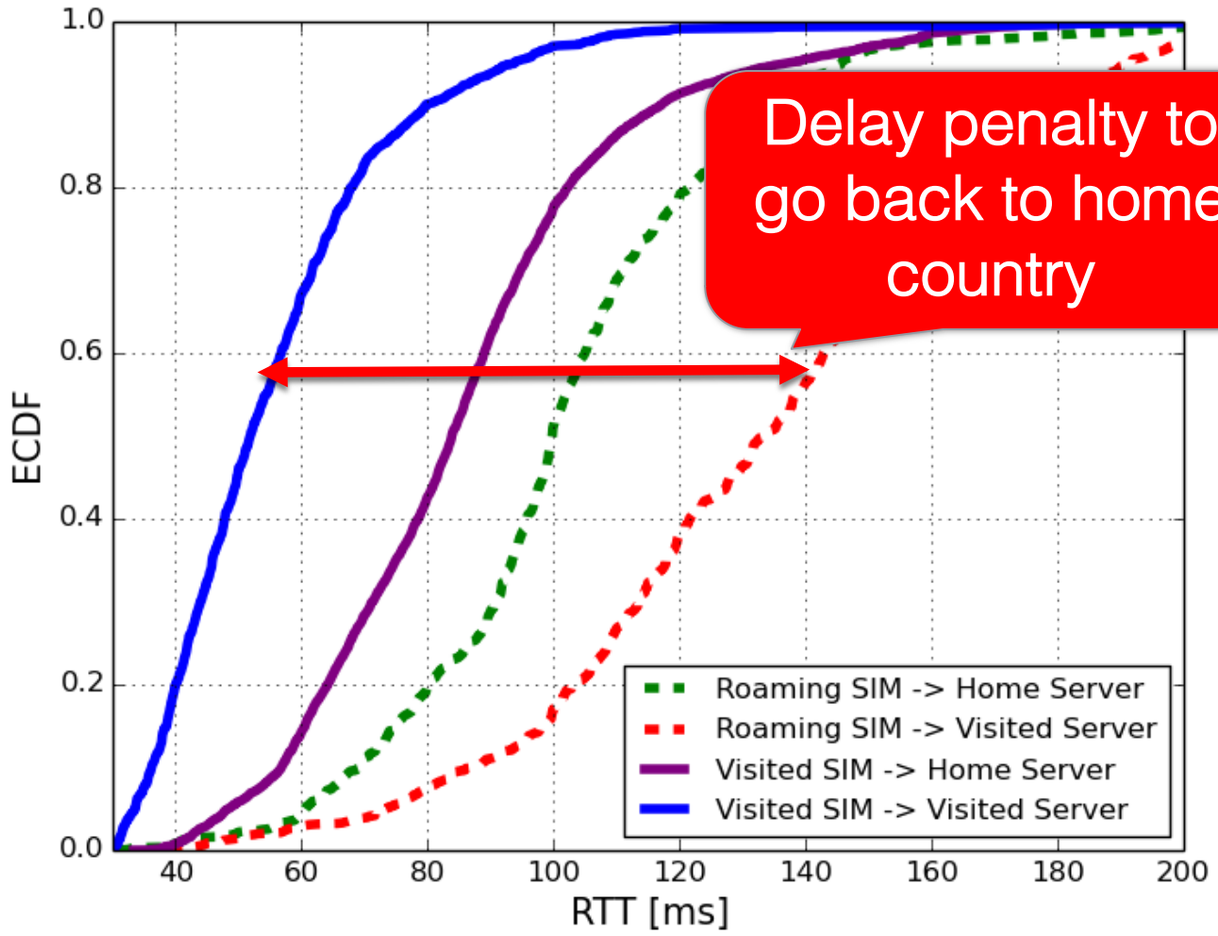




ECDF: Empirical Cumulative Distribution Function

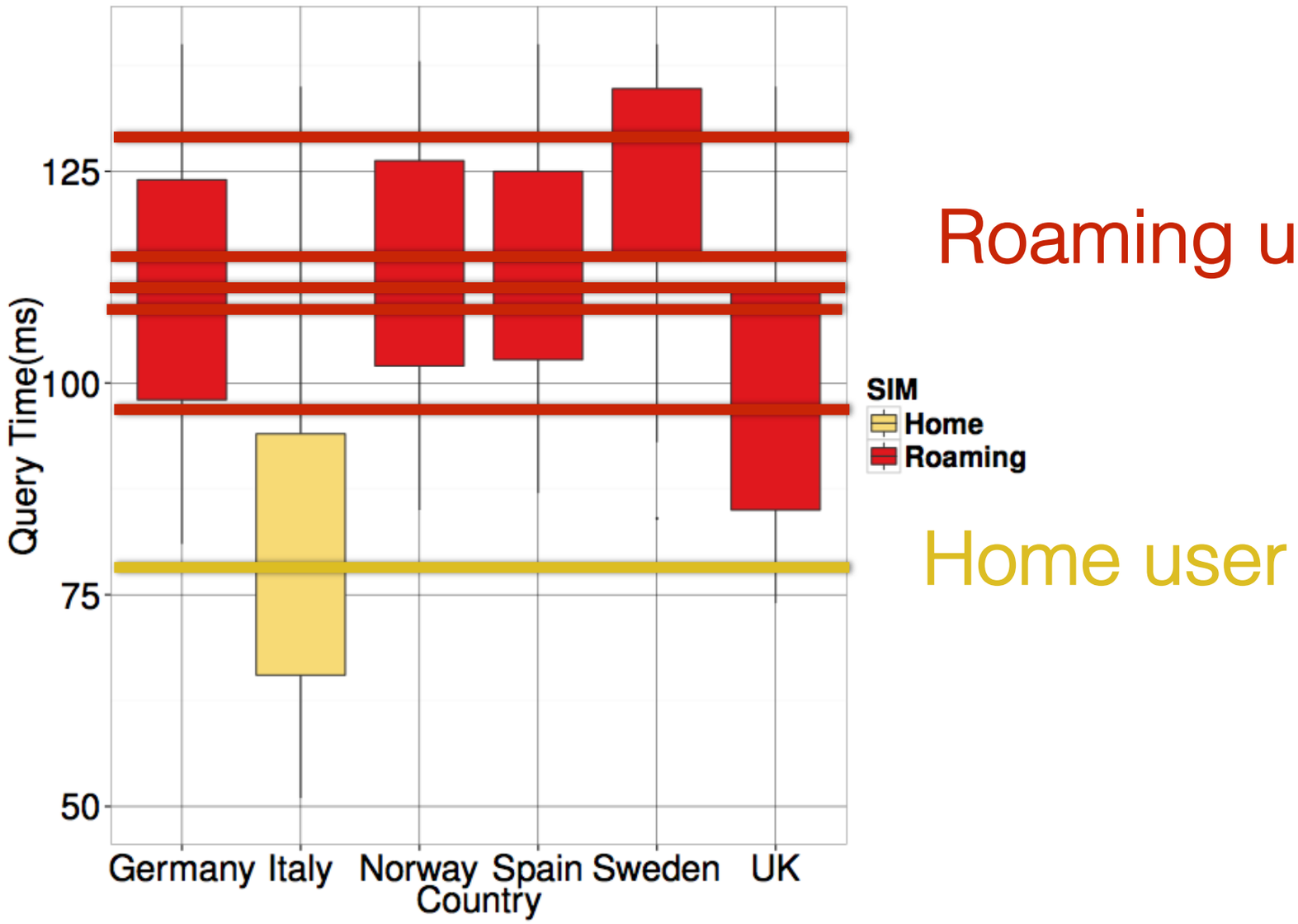
Roaming Setup and Performance: Delay implications





ECDF: Empirical Cumulative Distribution Function

Roaming Setup and Performance: DNS implications



Roaming user

Home user

- For the home user the query time is significantly lower in average than for the other five roaming users

Outline

- Motivations
- Background
- Experimental setup: MONROE-Roaming
- Measurements:
  - Roaming setup and performance
  - VoIP
  - Content discrimination
- Roaming results
- Experience and conclusion

VoIP and Content Discrimination: Measurements

- Traffic differentiation measurements using three applications (FaceTime, Facebook Messenger, WhatsApp) to determine potential traffic differentiation in roaming

We do not observe any traffic differentiation on any of the 16 MNOs we measure.

- Ooniprobe web connectivity test

We found no evidence of additional content discrimination

Geo-restriction rules are the same “as home”

Outline

- Motivations
- Background
- Experimental setup: MONROE-Roaming
- Measurements:
  - Roaming setup and performance
  - VoIP
  - Content discrimination
- Roaming results
- Experience and conclusion

Roaming Experience

- Synchronizing the measurements was the most challenging part
    - Synchronization over email (and sometimes phone, text, skype, smoke signals…)

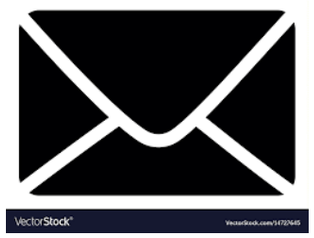
- Re-purposing MONROE software was straightforward (thanks MONROE Engineering team!)
    - Marvin MONROE – a scheduling daemon https://github.com/MONROE-PROJECT/Scheduler

- Taking care of MONROE nodes was challenging at times
    - Needed intervention at the deployment site, sometimes had to re-configure the nodes at every SIM change…

Conclusion and Future Work

- Home-Routed Roaming is the norm for the MNOs we measured and this is going to stay there!
- Delay penalties on the roaming user
- No traffic differentiation or content discrimination
- Future work: exploration of potential performance penalties on actual end-user Quality of Experience (QoE)

Happy Roaming to everybody!!!



Ali.safari@dal.ca

https://www.MONROE-project.eu/

Dataset

The code and the dataset collected is open to the community:

https://www.it.uc3m.es/amandala/roaming.html