

Problem & Motivation

- ▶ **Mobile data traffic is surging**, data roaming is increasingly popular.
- ▶ Large-scale internet measurement platforms only exist for fixed line connections, **mobile networks mostly ignored**.
- ▶ Cellular networks **differ in terms of measurement requirements** and objectives (calling, messaging, metered connections, zero rating offers, etc).
- ▶ A mobile-app-based approach impairs background user activity and is not suited for accurate technical measurements.
- ▶ It is especially hard to measure the roaming situation in a **controlled environment**.

Geographic Decoupling of Modem and SIM

Physically moving devices and SIM cards between countries to enable measurements in a roaming environment is costly and does not scale well.

Therefore we developed an approach to **geographically detach the SIM card** from the modem by **tunneling the SIM card's protocol** over the public Internet and emulating its signal on the LTE modem. This allows us to test roaming effects on a large number of operators without physically move any hardware between different countries.

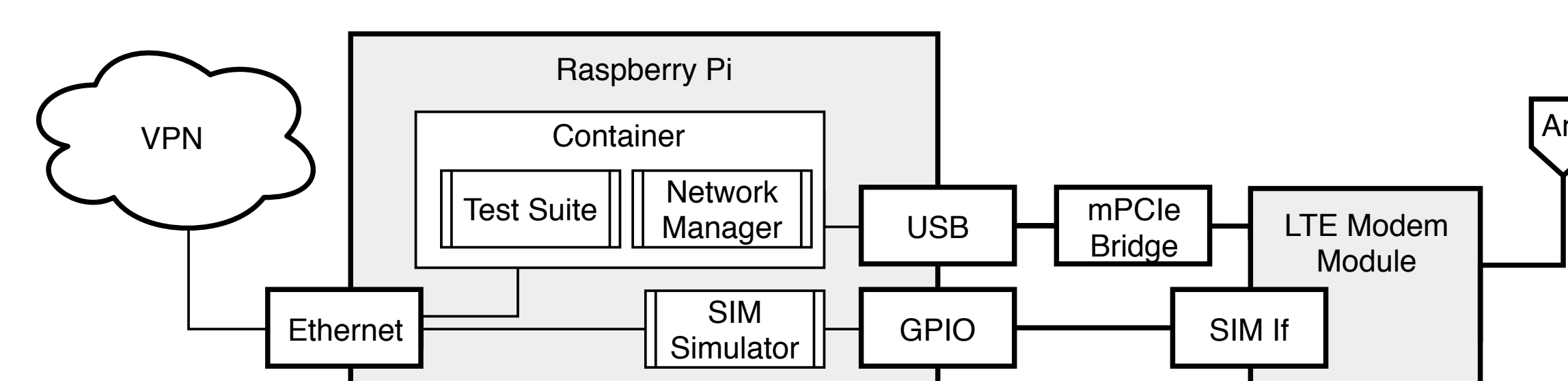


Figure 3: Design of our measurement probes

Measurement Framework Architecture

- ▶ The **measurement probe** consists of a single board computer with an LTE modem that is connected via USB. The board's GPIO pins are connected to the SIM interface on the modem and emulate a physical SIM card.
- ▶ The **SIM provider** consists of multiple SIM cards with individual SIM card readers that are connected via USB to a host computer. Since those SIM card readers are cheap and easily available, our framework allows us to add arbitrary distributed SIM cards from other sources and test them throughout our measurement probes.

The distinct parts of our infrastructure **communicate through a VPN**. The **tunnel connection** between a measurement probe and the SIM provider **forms a virtual circuit**, where one SIM card can be connected to exactly one modem. Being able to connect any SIM card with any radio module regardless of geography **boosts automatability** of tests across a large number of SIMs and radio networks.

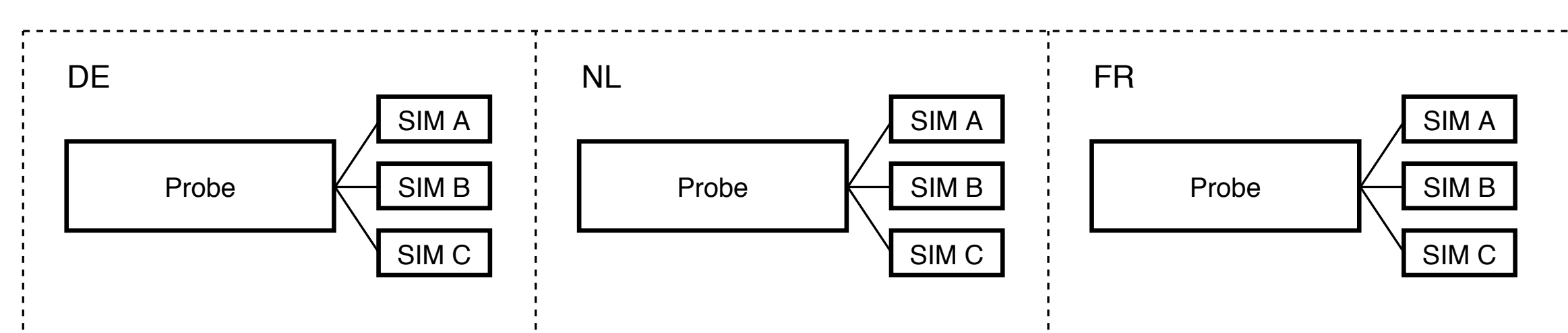


Figure 1: Naive architecture, exponential growth of used SIM cards, hard to maintain

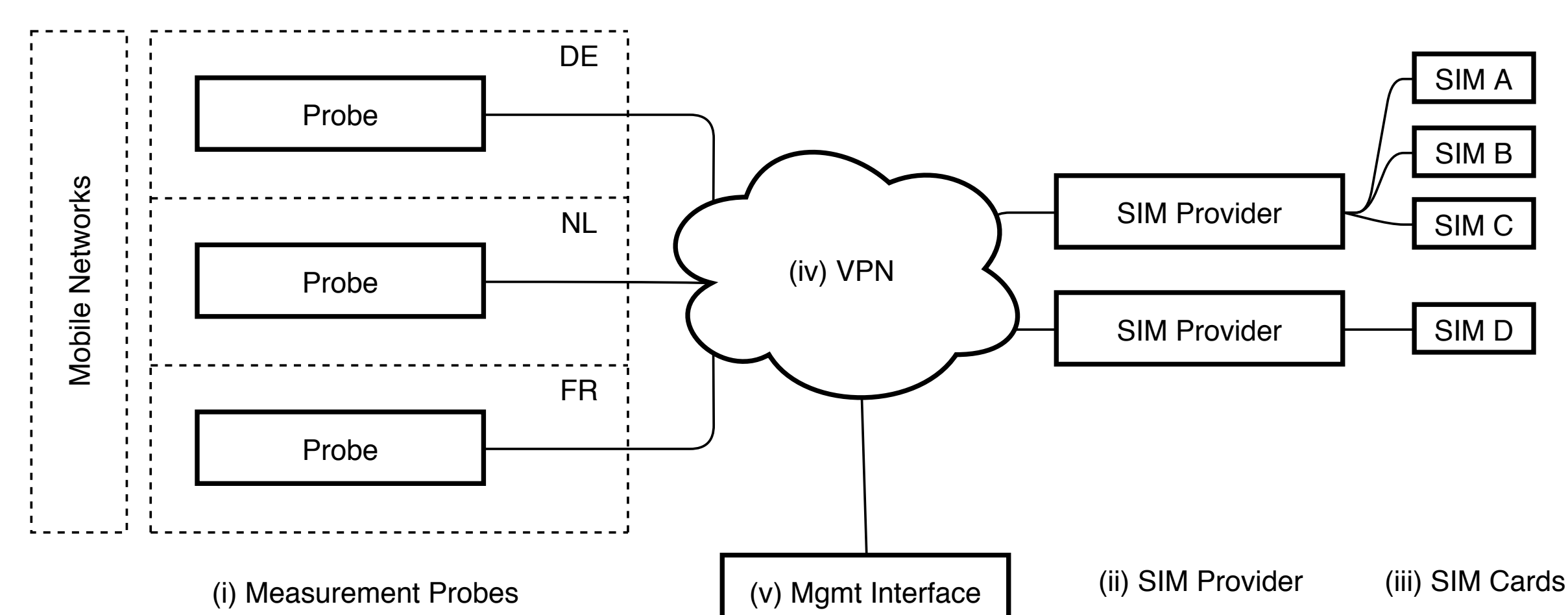


Figure 2: Our architecture allows every probe to use SIM cards attached to SIM providers, independent from the geographical location of probe and SIM card

Current Deployment State

- ▶ Deployed in Europe
 - ▷ Austria, France, Germany, Netherlands, Spain, United Kingdom
 - ▷ Total of 290 million people
- ▶ Open and scalable design
 - ▷ Easily extendable

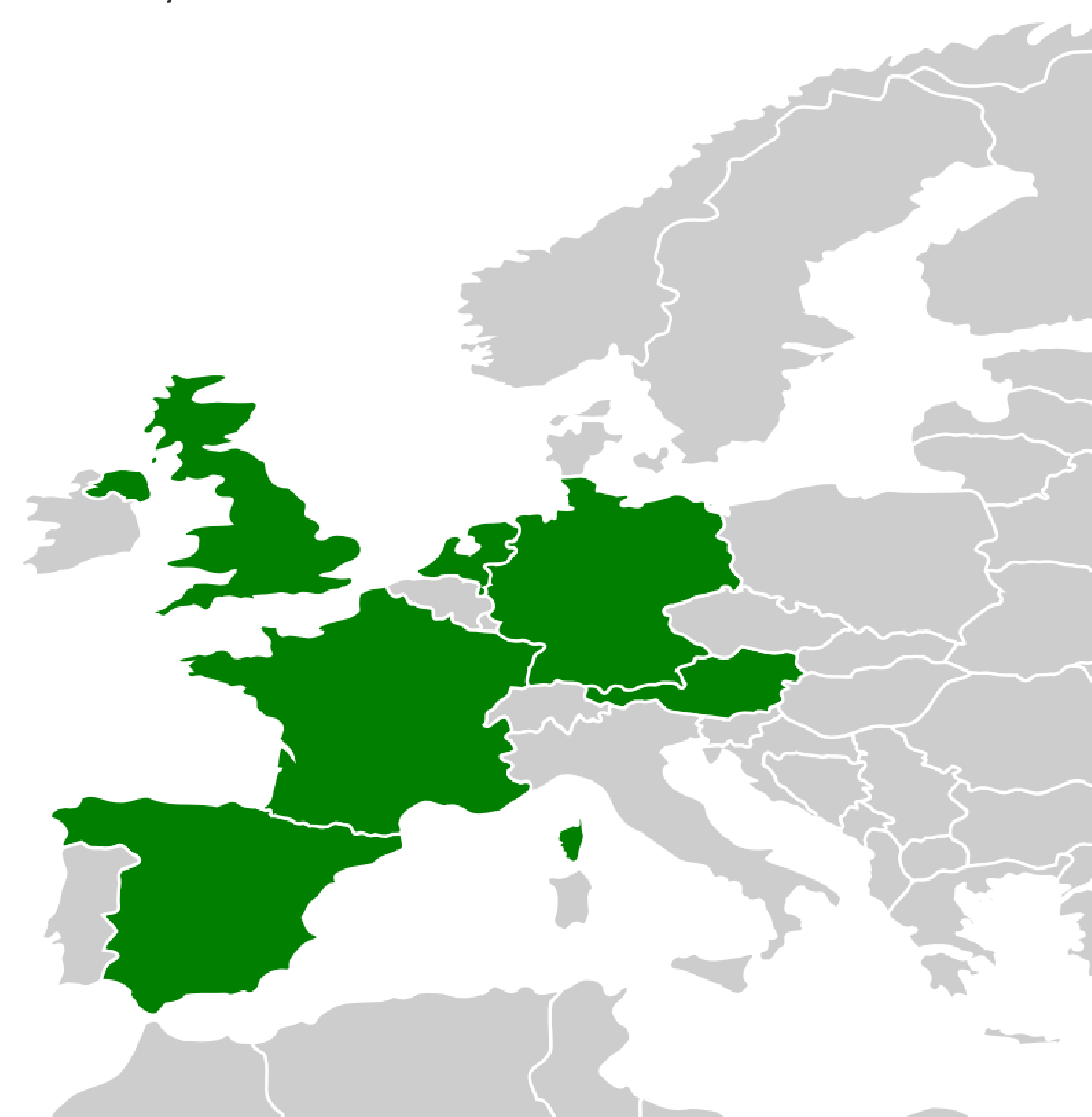


Figure 4: Current coverage of our measurement framework

Accomplishments

- ▶ Our Framework **enables qualitative measurements** in a controlled environment.
- ▶ **Scalable, open design, easily extensible**
 - ▷ Linear increase in costs per new probe
 - ▷ Practically no additional costs for new SIM cards