Implications of Roaming in Europe

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Outline

• Motivations

• Background

• Experimental setup: MONROE-Roaming

• Measurements:
  • Roaming setup and performance
  • VoIP
  • Content discrimination

• Roaming results

• Experience and conclusion
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Roaming in the European Union
15 June 2017
#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?
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SGW: Serving Gateway
PGW: Packet Data Network Gateway
IPX: IP Packet eXchange

Mobile Node (home user)
- eNodeB
- SGW
- MME
- HSS
- AAA
- PGW

Further (mobile) network operators
- R
- PGW

Mobile Node (roaming user)
- eNodeB
- SGW
- MME
- HSS
- AAA
- PGW

Home network
- SGW
- PGW
- eNodeB

IPX network
- SGW
- PGW
- MME
- HSS
- AAA
- PGW

Visited network
- SGW
- PGW
- MME
- HSS
- AAA
- PGW

Internet
- Home-Routed roaming (HR) → Local Breakout (LBO) → IPX Hub Breakout (IHBO) → Internet

Home-routed Roaming
- IPX Hub Breakout
- Local Breakout
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MONROE-Roaming Platform

- MONROE-Roaming nodes

<table>
<thead>
<tr>
<th>Design Aspect</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node Platform</td>
<td>APU2C4</td>
</tr>
<tr>
<td>Node Configuration</td>
<td>2xMC7455</td>
</tr>
<tr>
<td>Node Hardware</td>
<td>1xAPU + 2xMC7455</td>
</tr>
<tr>
<td>Operating System</td>
<td>Debian 9 Stretch</td>
</tr>
<tr>
<td>Modem Type</td>
<td>Sierra MC7455 CAT6 miniPCIe modem</td>
</tr>
</tbody>
</table>
MONROE-Roaming Platform

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

### Mobile Network Operators

<table>
<thead>
<tr>
<th>Country</th>
<th>Operator 1</th>
<th>Operator 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO</td>
<td>Telia NO</td>
<td>Telenor NO</td>
</tr>
<tr>
<td>SE</td>
<td>Telia SE</td>
<td>Telenor SE</td>
</tr>
<tr>
<td>UK</td>
<td>Vodafone UK</td>
<td>EE</td>
</tr>
<tr>
<td>DE</td>
<td>Vodafone DE</td>
<td>T-Mobile</td>
</tr>
<tr>
<td>ES</td>
<td>Vodafone ES</td>
<td>Movistar</td>
</tr>
<tr>
<td>IT</td>
<td>Vodafone IT</td>
<td>TIM</td>
</tr>
</tbody>
</table>
• Measure one MNO at a time (all nodes have the SAME SIM at the same time).

• Measure the visited network natively, where possible.
### MNOs

<table>
<thead>
<tr>
<th>Country</th>
<th>MNO 1</th>
<th>MNO 2</th>
</tr>
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<tbody>
<tr>
<td>NO</td>
<td>Telia NO</td>
<td>Telenor NO</td>
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</tr>
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<td>UK</td>
<td>Vodafone UK</td>
<td>EE</td>
</tr>
<tr>
<td>DE</td>
<td>Vodafone DE</td>
<td>T-Mobile</td>
</tr>
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Experimental Setup
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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
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Roaming Setup and Performance: Delay implications

99% of users experienced the RTT less than 120 ms

ECDF: Empirical Cumulative Distribution Function
Roaming Setup and Performance: Delay implications

ECDF: Empirical Cumulative Distribution Function

Longer the geographical distance implies the longer RTT
Roaming Setup and Performance: Delay implications

ECDF: Empirical Cumulative Distribution Function

GPRS tunnel is slower than native Internet
Roaming Setup and Performance: Delay implications

ECDF: Empirical Cumulative Distribution Function

Delay penalty to go back to home country
Roaming Setup and Performance: DNS implications

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

https://ooni.torproject.org
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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!!!

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https://www.MONROE-project.eu/
The code and the dataset collected is open to the community:

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