Making Cellular Networks More Efficient By Roaming-in-Place

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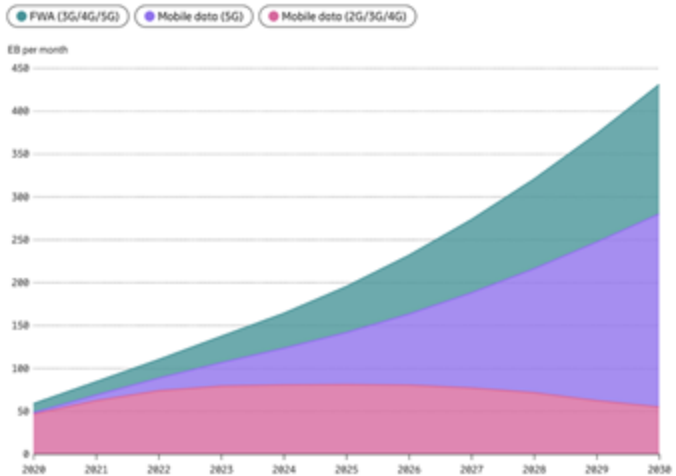
Scaling capacity to meet demand

- Major challenge operators are facing is the increase in mobile traffic
- **Cooper's law** - observed that wireless per link data rates per-user doubles every 30 months (akin to Moore's Law)

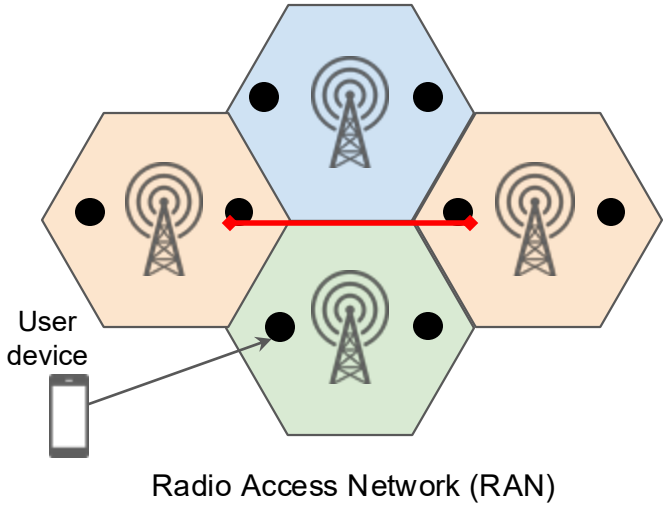


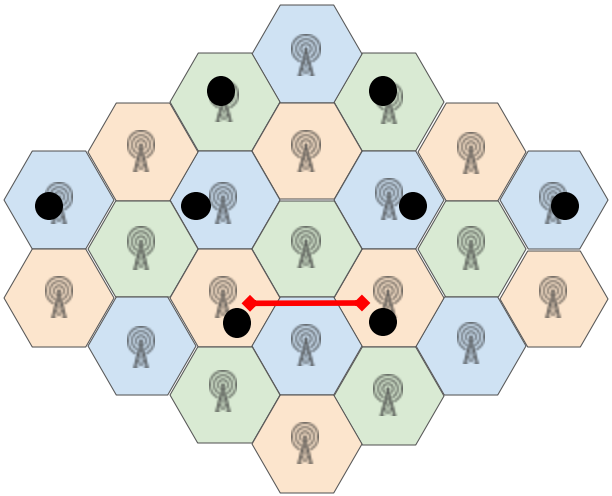
Global mobile network data traffic

Mobile data traffic outlook. Ericsson. (2025)

Densification

(Carefully) deploying more towers → more capacity available per user

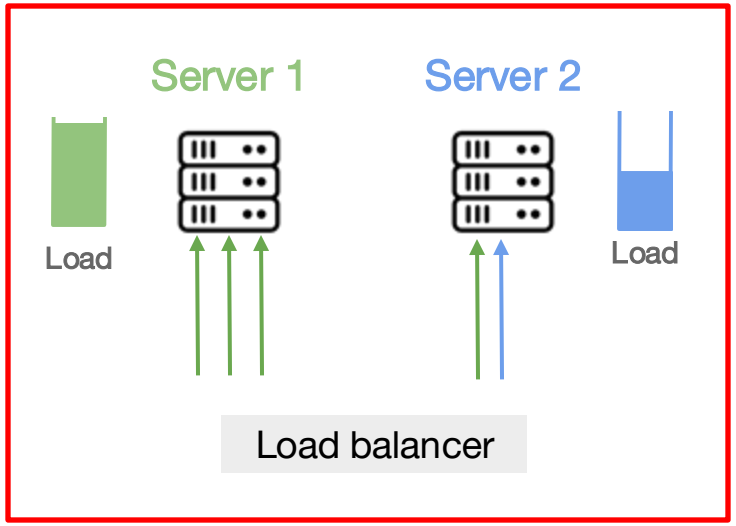




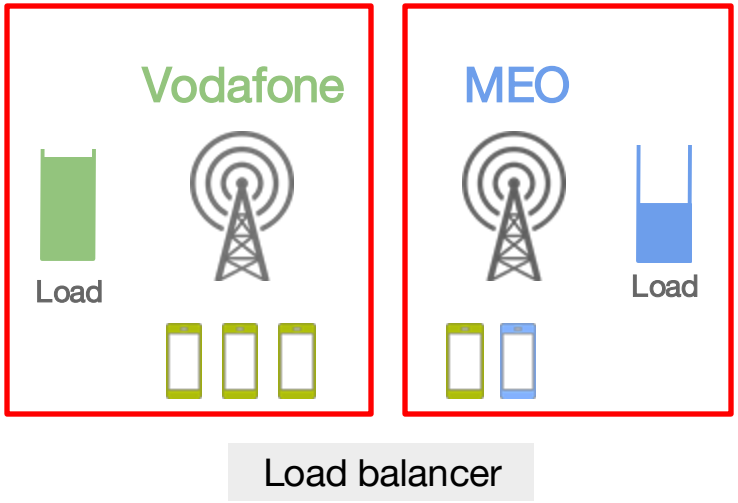
But also increases the likelihood of interference between towers

We are approaching the limits of densification and hence facing the end of Cooper’s law.

Inspiration: load balancers in online services



Our idea: load balances between operators



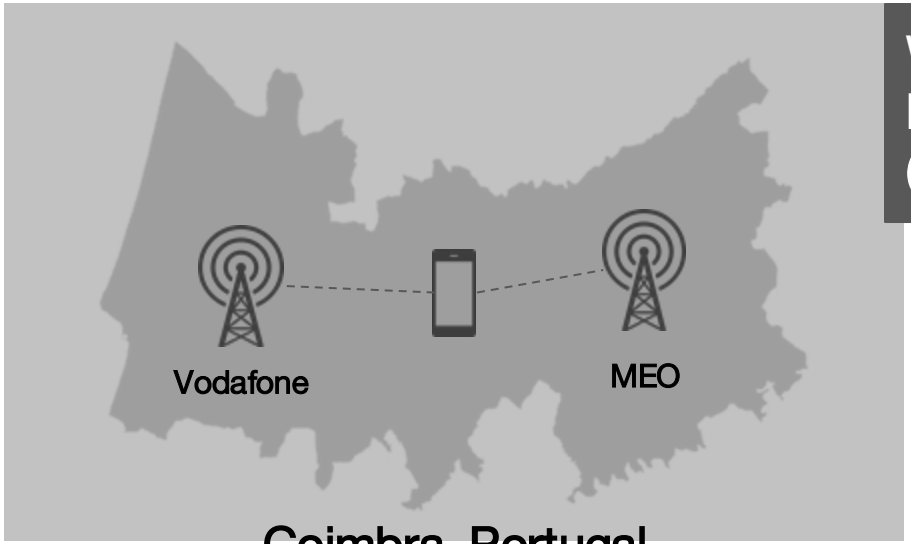
Intuitively, saves operators from having to provision for peak demand

We’re all familiar with roaming in a cellular context …

Roaming is limited to scenarios of
no overlapping coverage.

Key idea: Roaming in areas of *overlapping* coverage

- Also use roaming when the operator is overloaded
- Particularly, in dense urban areas



We call this idea:
Roaming-in-place (RinP)

Why is RinP a good idea?

1. More efficient capacity scaling
2. Improved performance and availability

RinP’s contribution is demonstrating that

fine-grained and *dynamic* user sharing

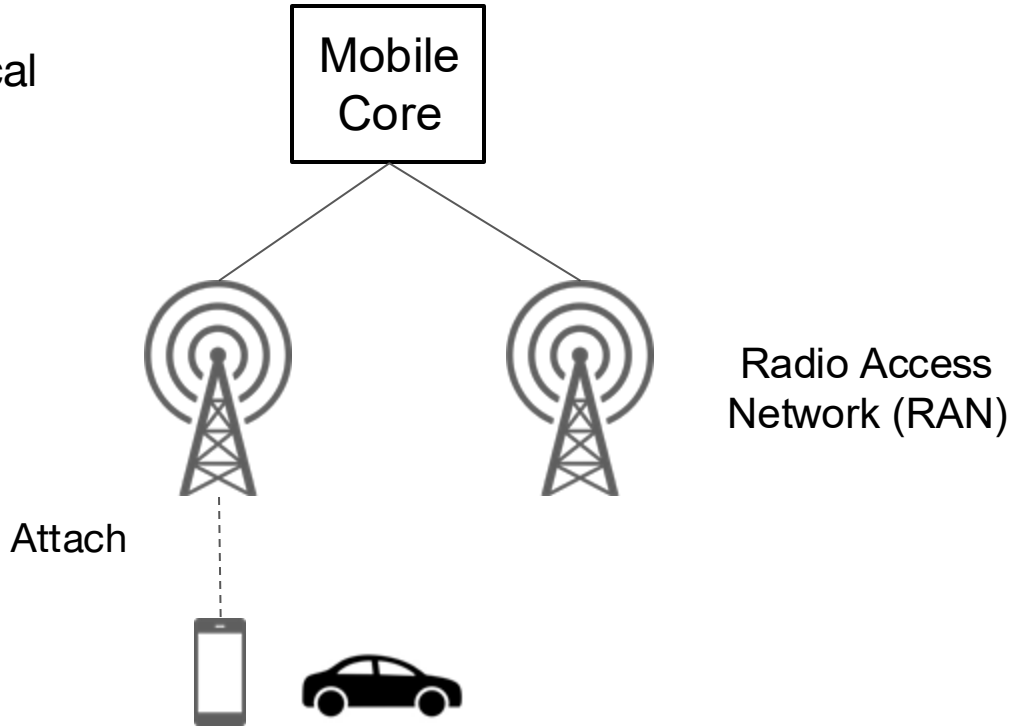
is feasible and beneficial.

Outline for the rest of this talk:

1. How RinP works
2. RinP prototype / performance
3. Evaluation of benefits

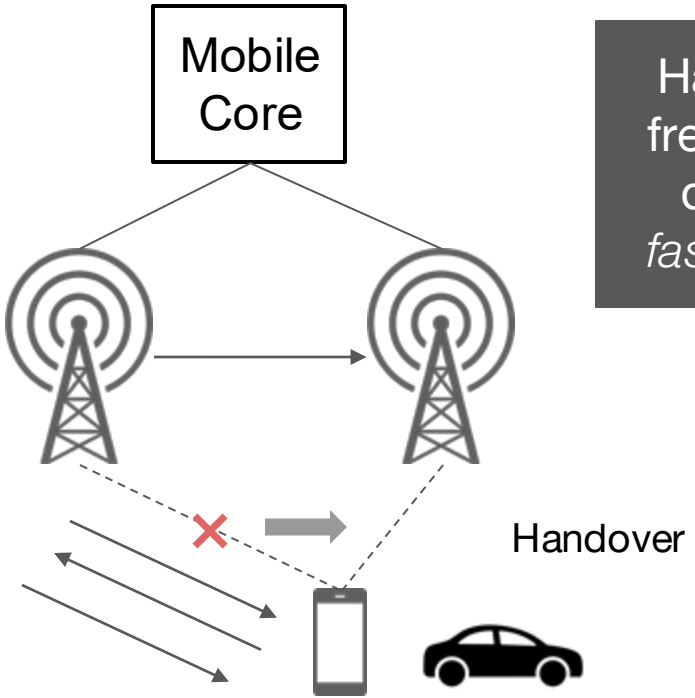
1. How does RinP work?

Let's start with a typical cellular network:



Handovers: fast and seamless

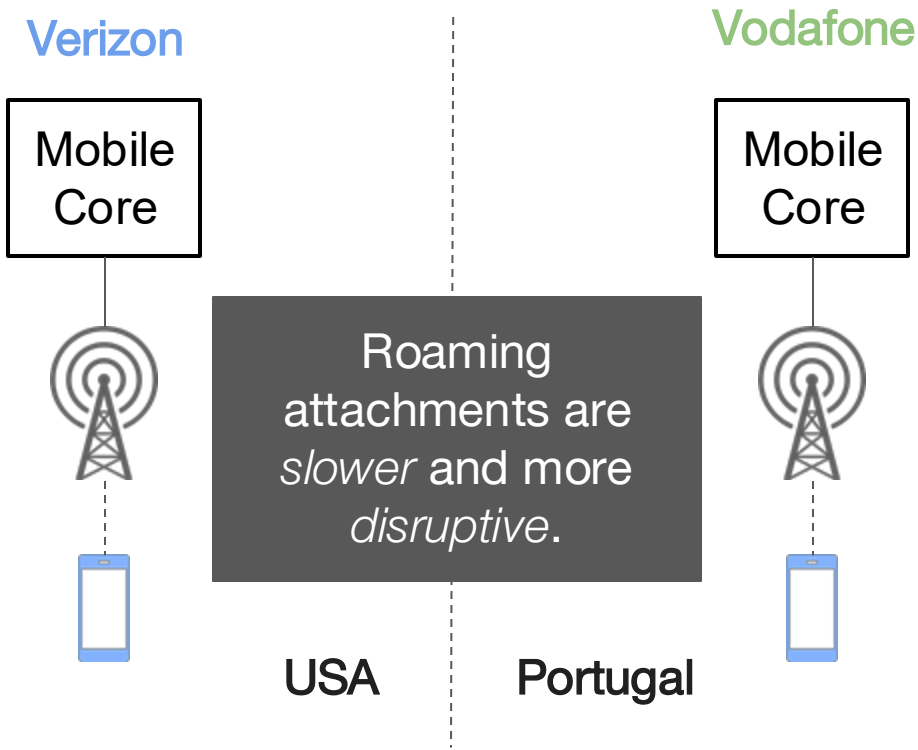
Let's start with a typical cellular network:



Handovers occur frequently and are designed to be *fast* and *seamless*.

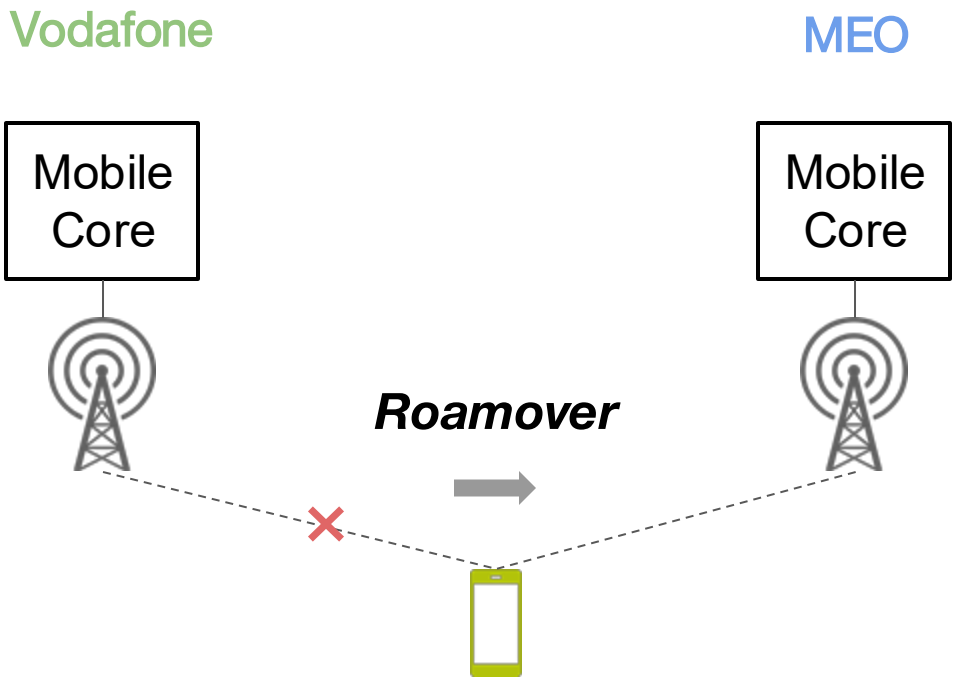
Roaming Attachments: slower and more disruptive

When roaming:



RinP introduces a new operation: roamover

RinP:



3GPP protocol

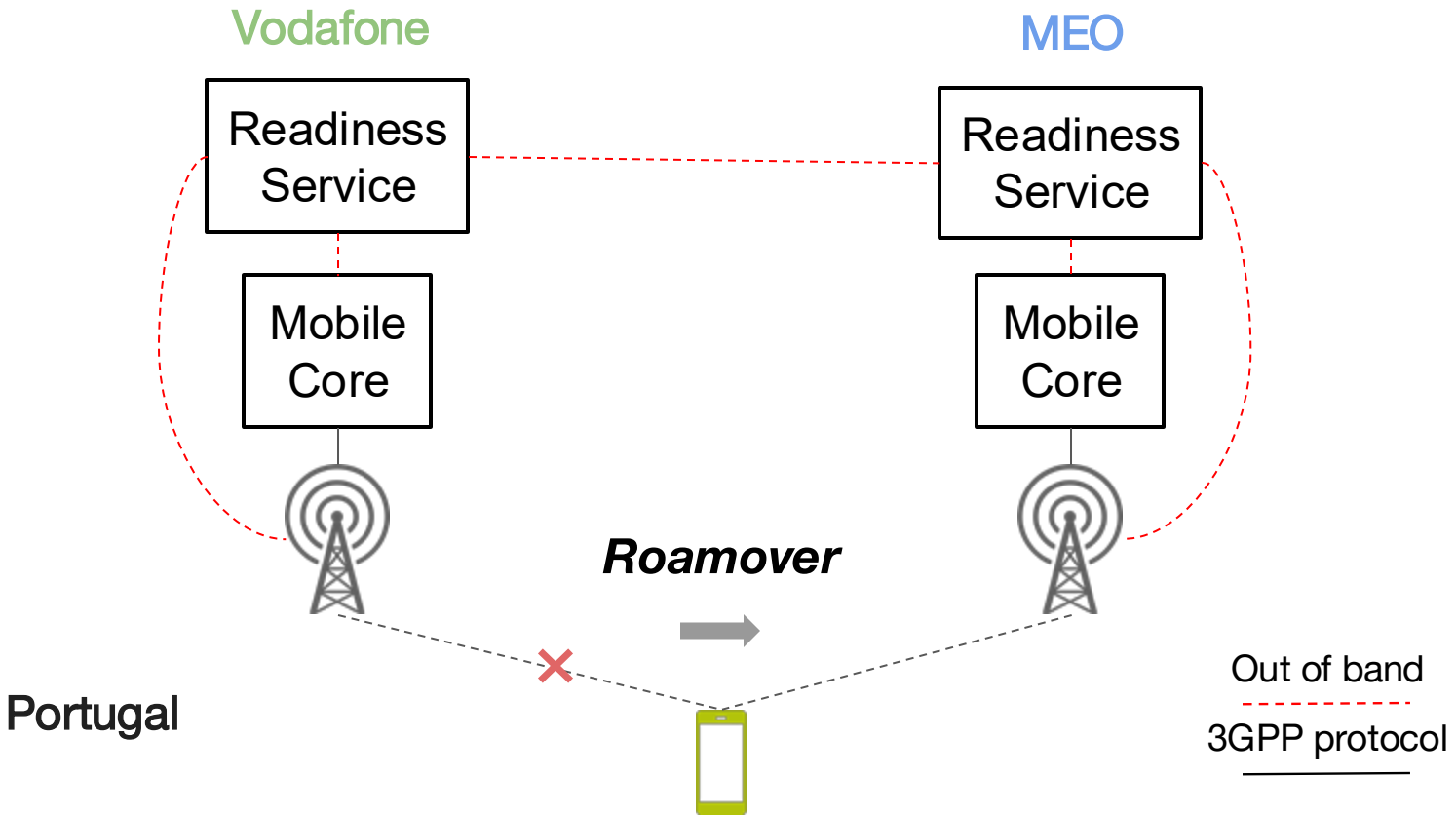
Challenges in implementing Roamovers

- Deployability: No changes to the 3GPP standard
- Making roamovers fast and seamless

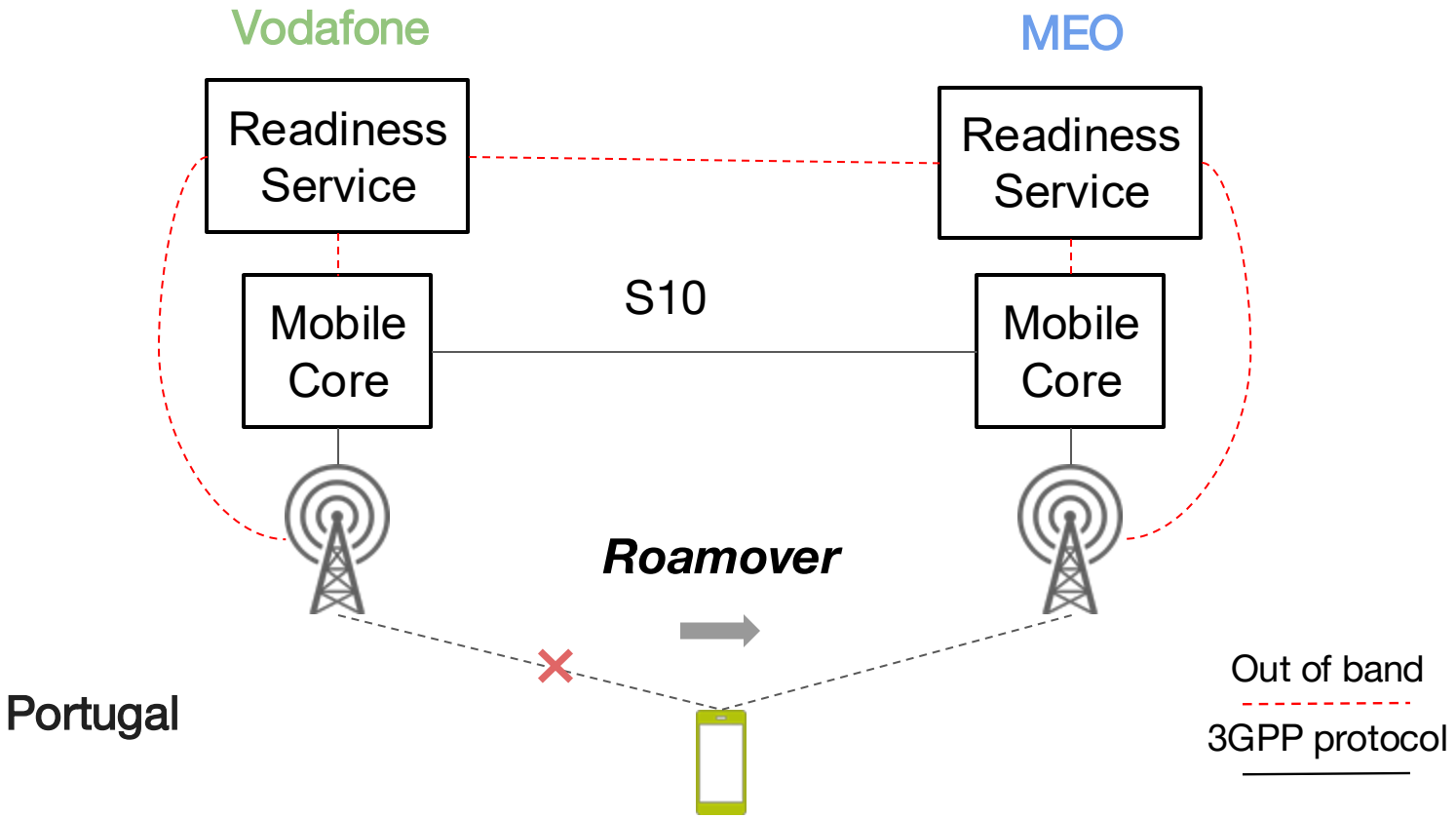
Design questions

1. How do we know what towers are available and willing to accept roamover users?
2. What's a technique that actually triggers the UE to switch networks in a way that's seamless/fast?
    a. Leverage the S10 interface
    b. "Trick" the UE into roaming

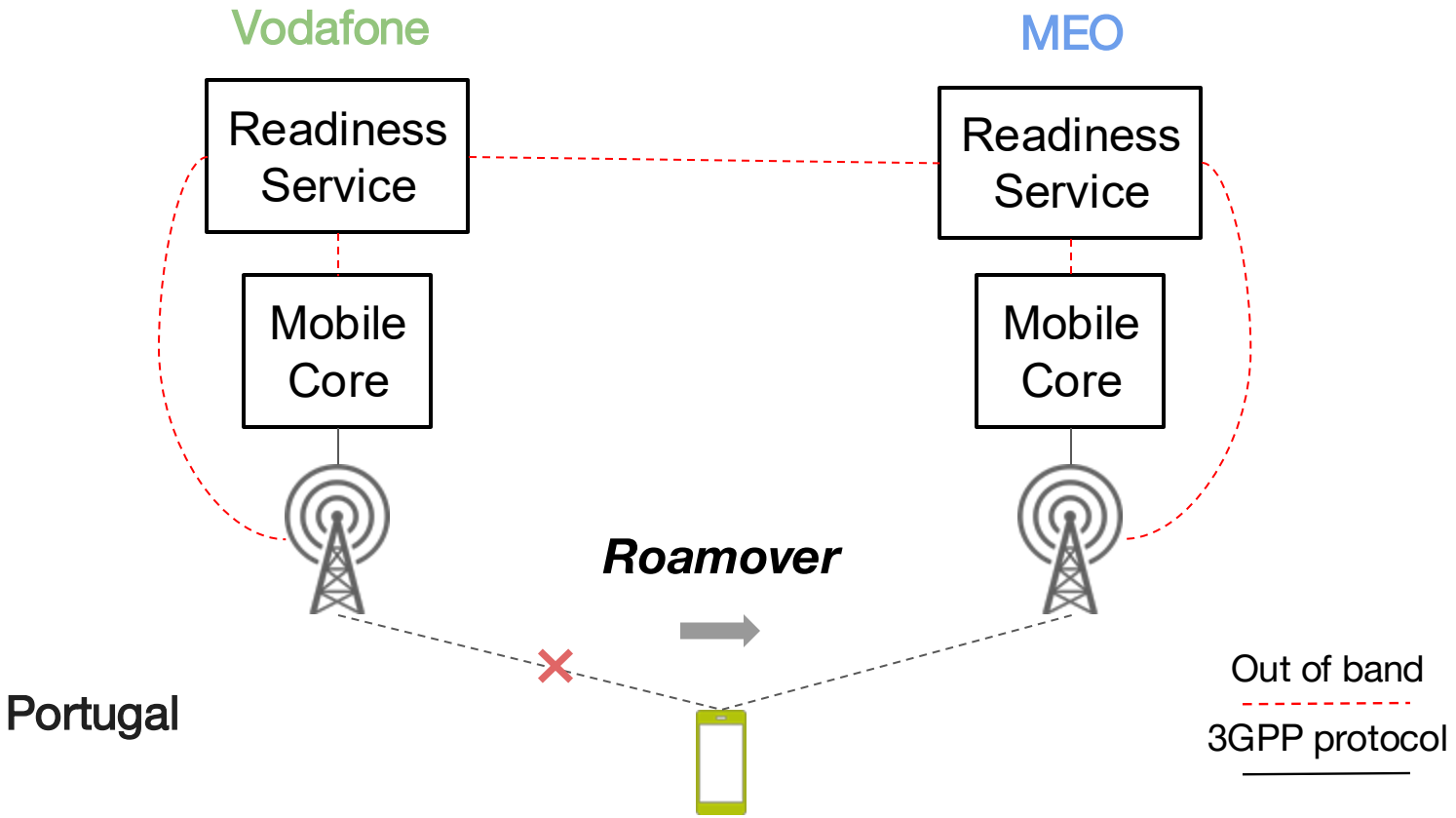
How does RinP work? - Readiness server



How does RinP work? - S10 Roamover



How does RinP work? – Detach Attach Roamover

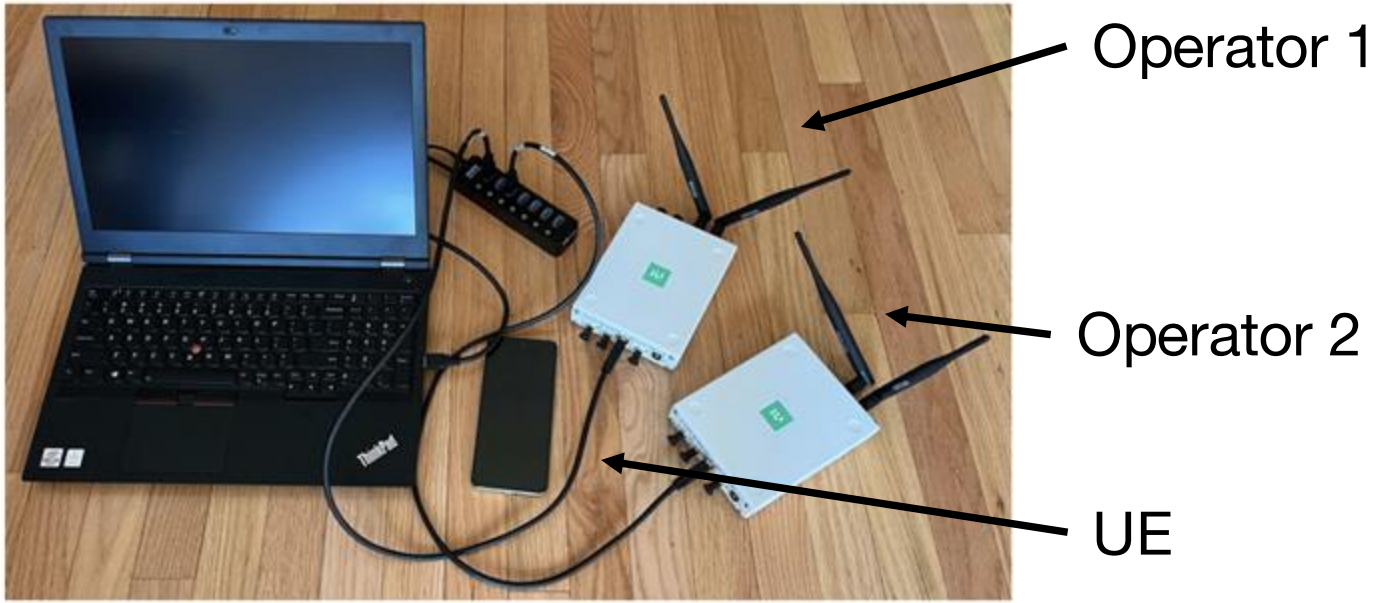


Key takeaways: Deployable today

- No changes to the 3GPP specification
  - Minimal changes to the RAN and core
  - Only requiring out of band messaging
- Seamless and fast

2. RinP Prototype / Performance

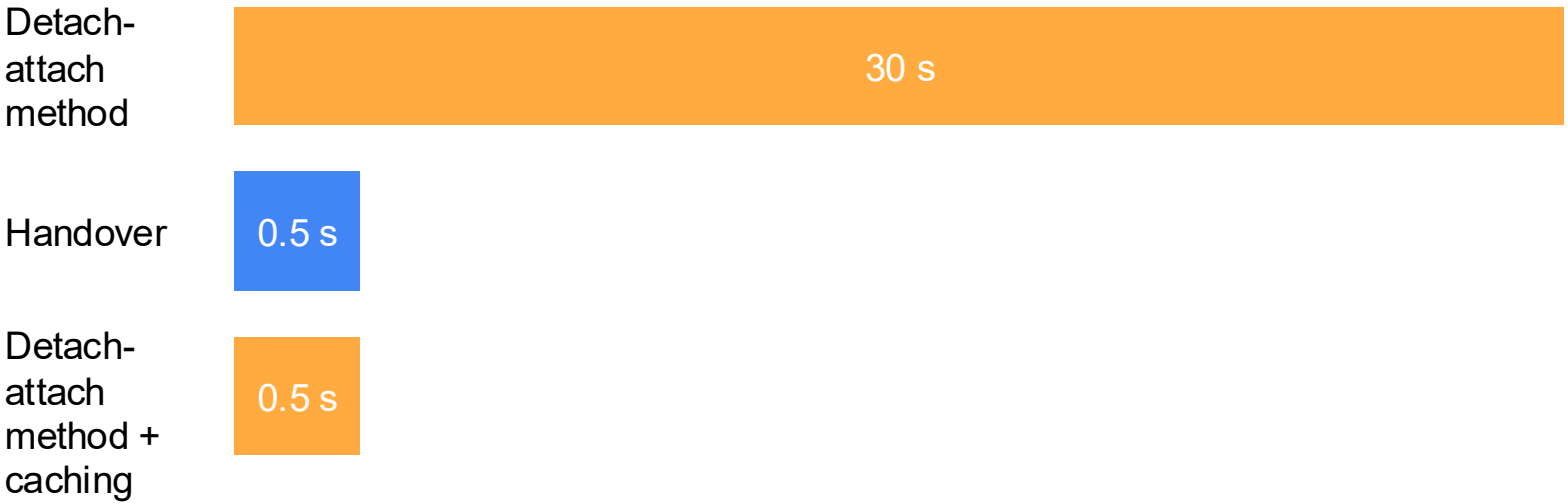
a) Prototype:



2. RinP Prototype / Performance

b) Performance:

Roamover time =



3. Evaluation of benefits

a) Efficient capacity scaling

- Built a simulation to find savings in provisioning cost

b) Improved availability and performance

- Measured real world availability and performance gains

3. Evaluation of benefits

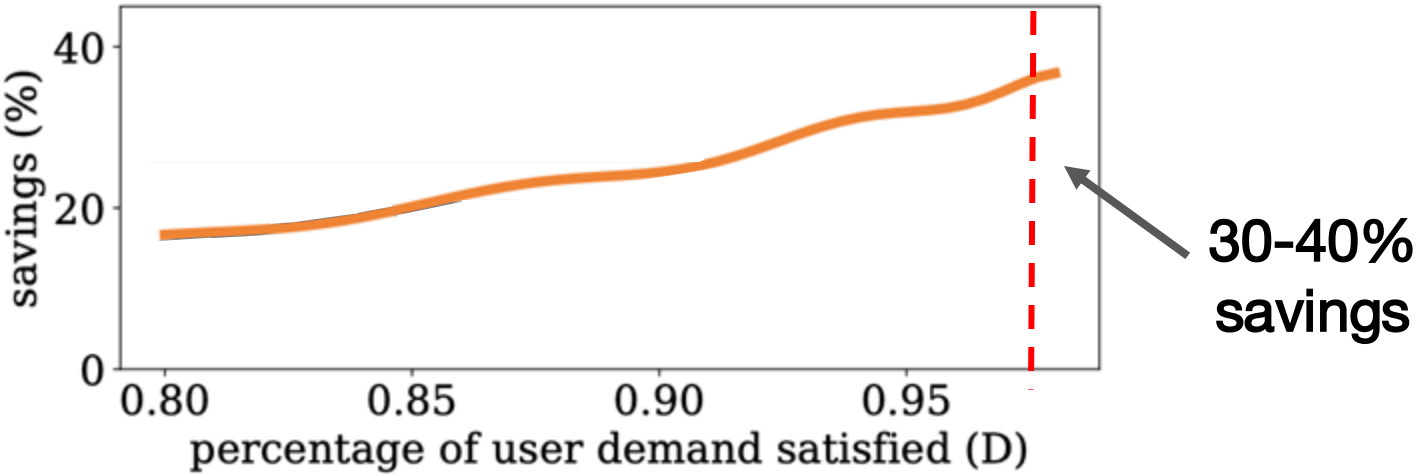
a) Efficient capacity scaling

- 2 operators
- Model load on both operator's networks
- Measure capacity needed to meet SLO with and without RinP
  - SLO = "meet over D% of user demand, at least 90% of the time"

3. Evaluation of benefits

a) Efficient capacity scaling

SLO = “meet over D% of user demand, at least 90% of the time”



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a) Efficient capacity scaling

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Scenario	Maximum signal strength gain	Maximum bandwidth gain
Mobile in Tokyo	10.98%	25.62%
Mobile in Berkeley	10.37%	722.32%
Stationary in Tokyo	7.55%	85.51%
Stationary in Berkeley	25.96%	254.28%

Thank you!

RinP aims to provide operators a way to scale their networks in a cost effective way in order to provide better performance and availability to their users with minimal disruption to operator practice.

Please check out our paper for:

- Detailed comparison to other forms of infrastructure/spectrum sharing
- Roamover protocol and performance details

Contact:

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