



CROSS

location proofs for smart tourism in the city

Author: Gabriel Antunes Maia

gabriel.maia@tecnico.ulisboa.pt



TÉCNICO LISBOA

Presenter: Rui Nuno Lopes Claro

rui.claro@tecnico.ulisboa.pt





Smartphones
the **travel agency**
Tourism
of this generation



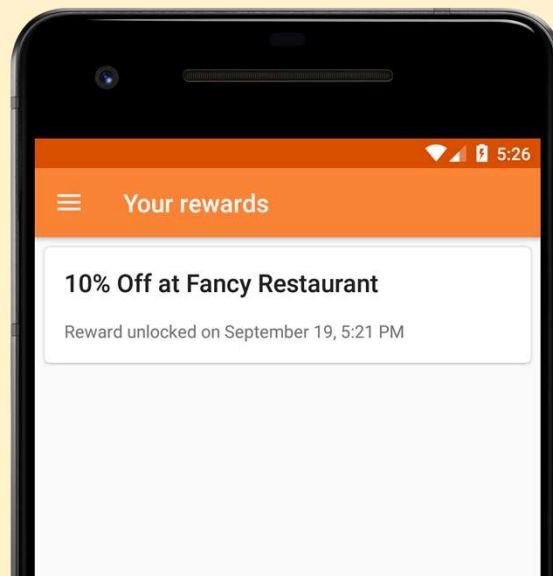
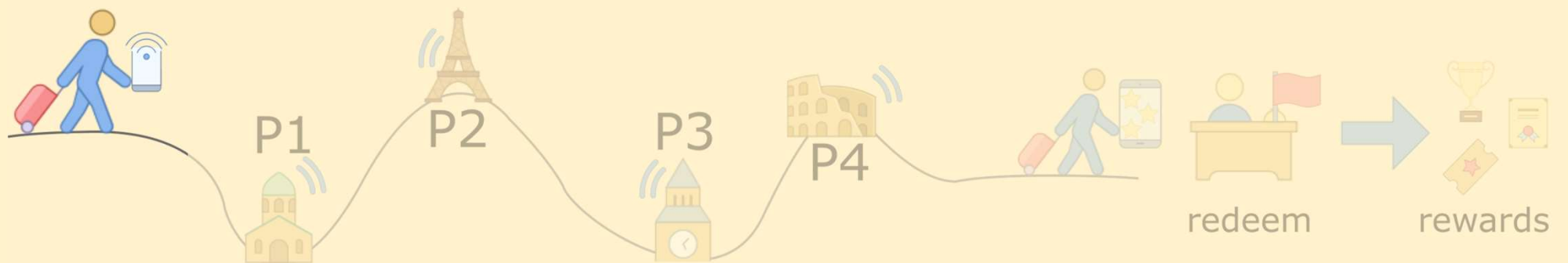
Locations compete
for tourist presence

Tourists want to say
I have been there!

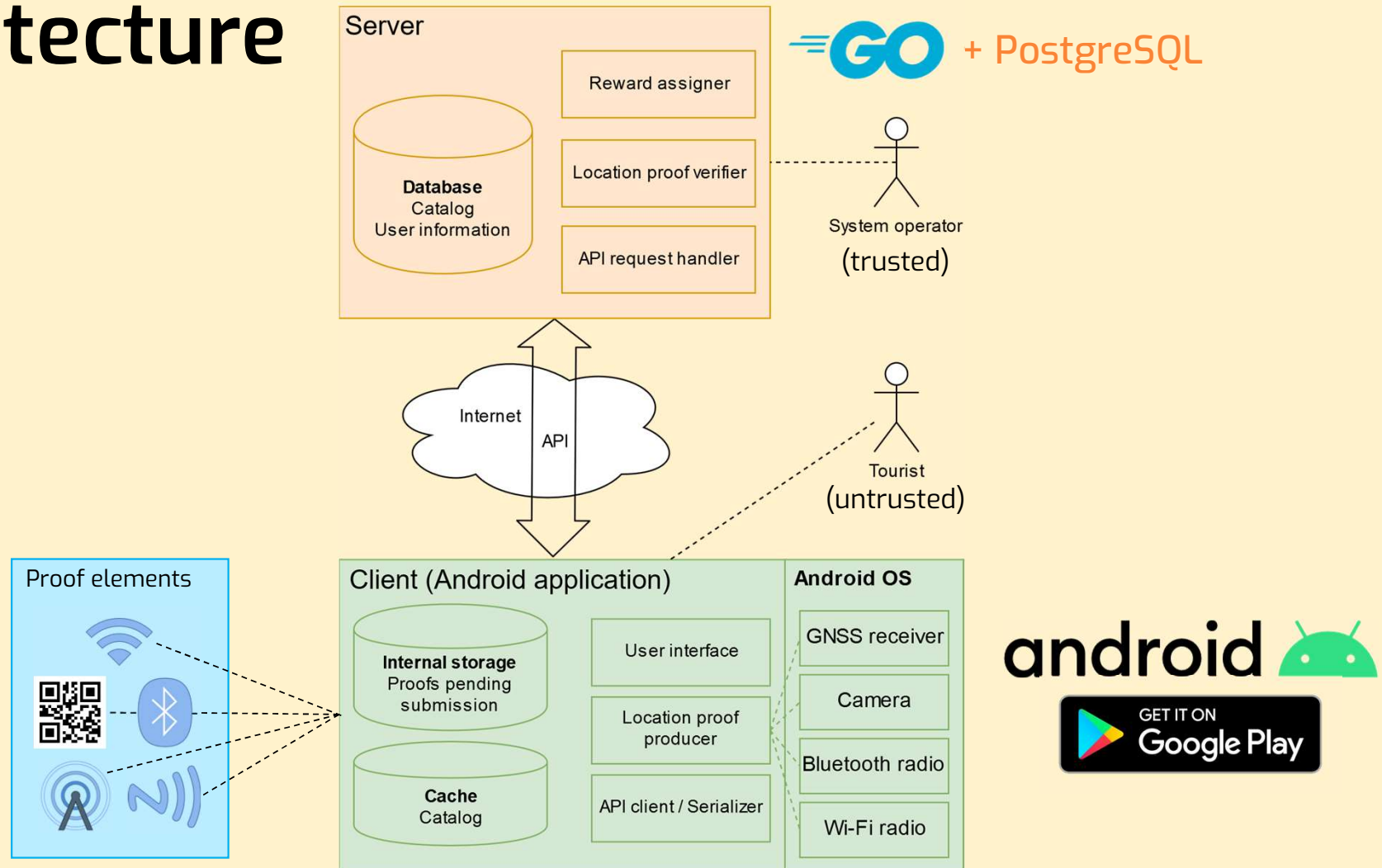
Plenty of infrastructure around...

Smart Cities

Rewarding tourists for their visits

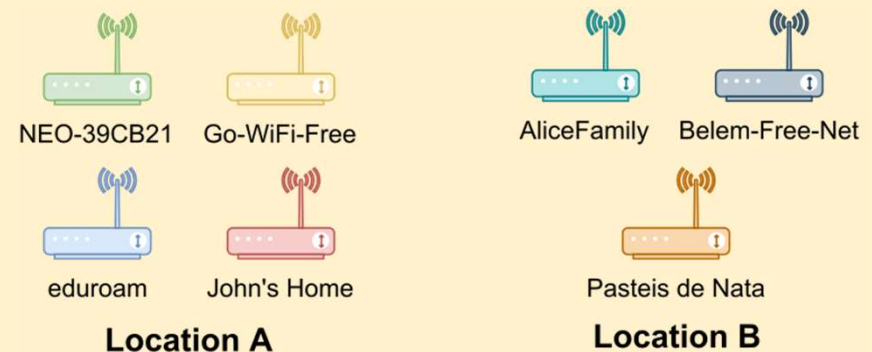


Architecture



Location proofs using Wi-Fi Scavenging

- Scan existing Wi-Fi networks
 - 3rd-party
- Server has a known list
 - Regular list updates required
- Client has part of the list
 - **Triggers** to identify location



94:CA:1E NEO-39CB21 @ 10:21 (trigger)
E3:21:09 Go-WiFi-Free @ 10:21
44:FA:EE eduroam @ 10:22
48:11:BC John's Home @ 10:34
39:DC:A2 Belem-Free-Net @ 11:12 (trigger)
02:1F:3D AliceFamily @ 11:15
0C:AF:E4 Pasteis de Nata @ 11:15

Attacks on Wi-Fi Scavenging



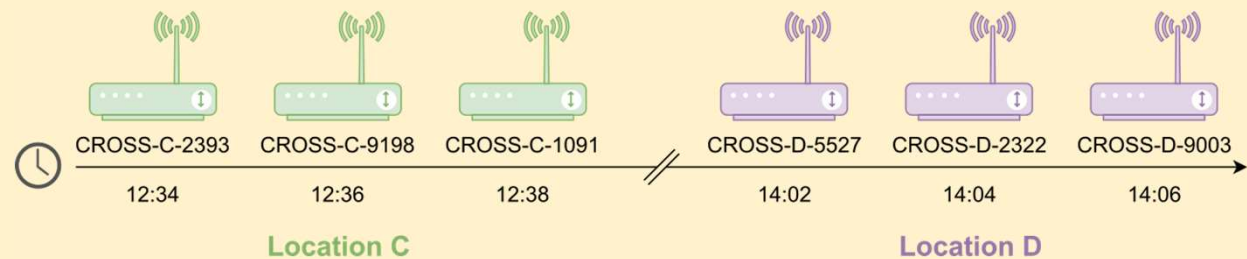
Find the secret once,
find it “forever”

- Forge location proofs
- Get undue rewards

Let's protect against this...

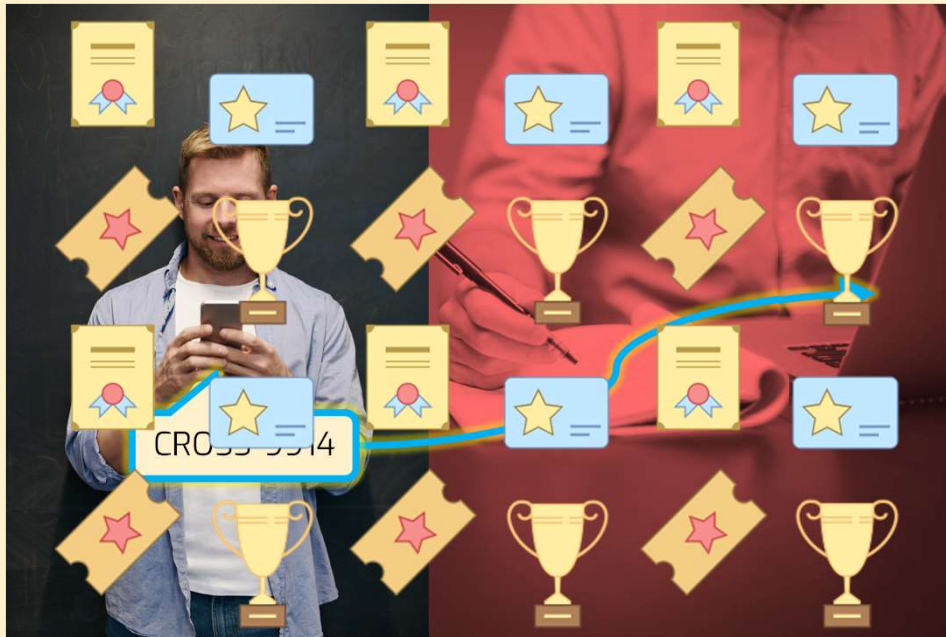
Location proofs using Wi-Fi AP Time-based One Time Password

- SSID changes every 2 minutes using seed-derived sequence
- Only server and AP know the secret seed
- Algorithm described in RFC 6238
2FA, e.g. Google Authenticator
- Proof of visit **time** and **duration**



2C:3E:B6 CROSS-C-2393 @ 12:34
2C:3E:B6 CROSS-C-9198 @ 12:36
2C:3E:B6 CROSS-C-1091 @ 12:38
5F:39:A0 CROSS-D-5527 @ 14:02
5F:39:A0 CROSS-D-2322 @ 14:04
5F:39:A0 CROSS-D-9003 @ 14:06

Attacks on Wi-Fi AP TOTP



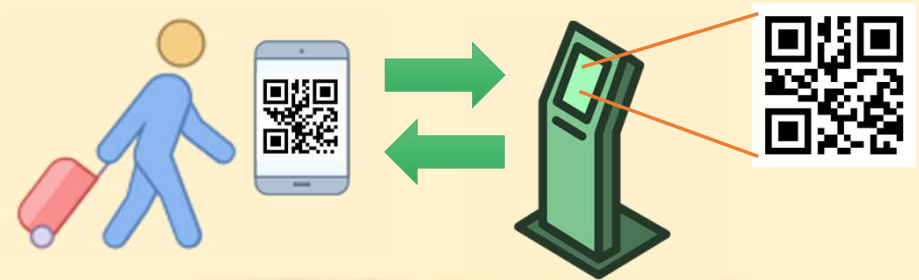
- Relay SSIDs to remote accomplice
requires more **effort!**
- Forge location proofs
- Get undue rewards

Let's protect against this...

Location proofs using a Kiosk

Completely different

- No wireless communication
- Uses QR codes
 - Something we can **see**
- Mutual authentication
- Prevents **Sybil** attacks



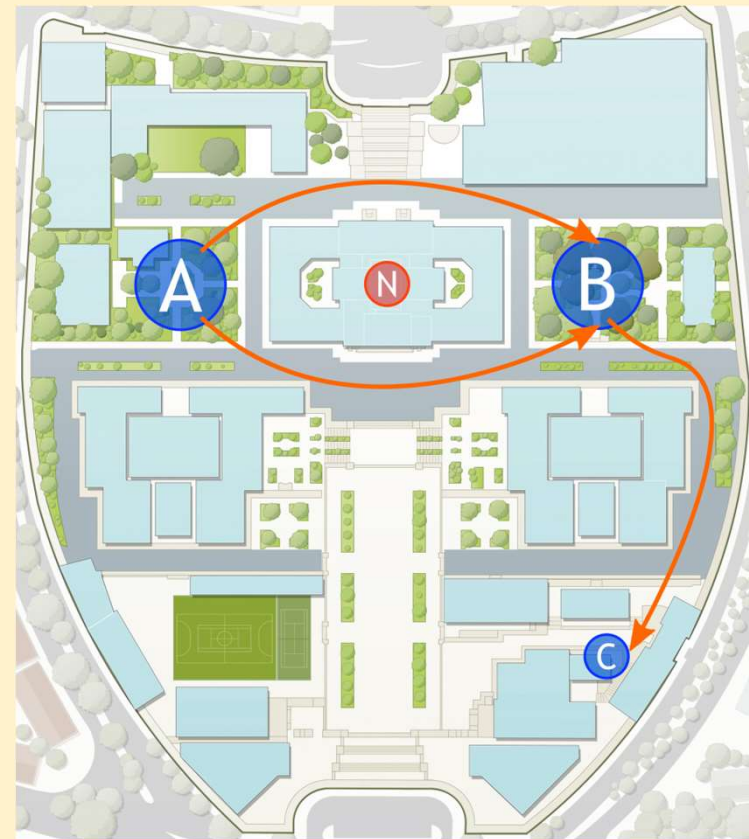
Kiosk is not always the solution

- Tourist satisfaction is important
- Use kiosk only when necessary and convenient
- Variety is good:
combine different strategies in different locations
 - Increase necessary attacker effort
 - Decrease deployment costs
- Architecture supports other proof strategies

Evaluation

Evaluation

- Tests with **30 users**
 - **34** different Android smartphones
- Test route with 3 locations (A, B, C, N)
 - Alameda campus of Instituto Superior Técnico

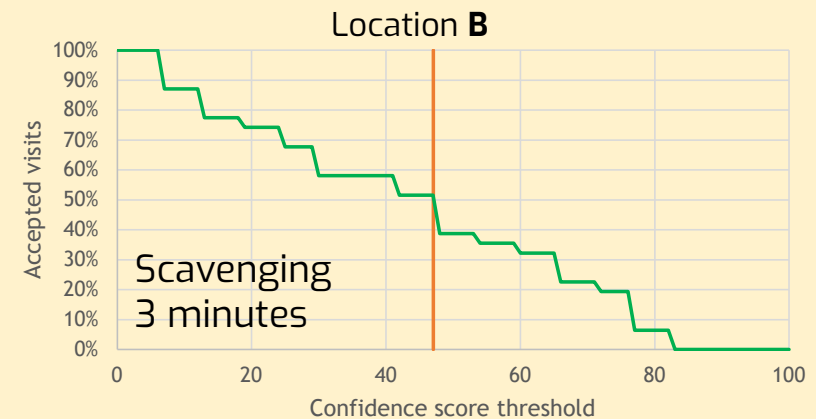
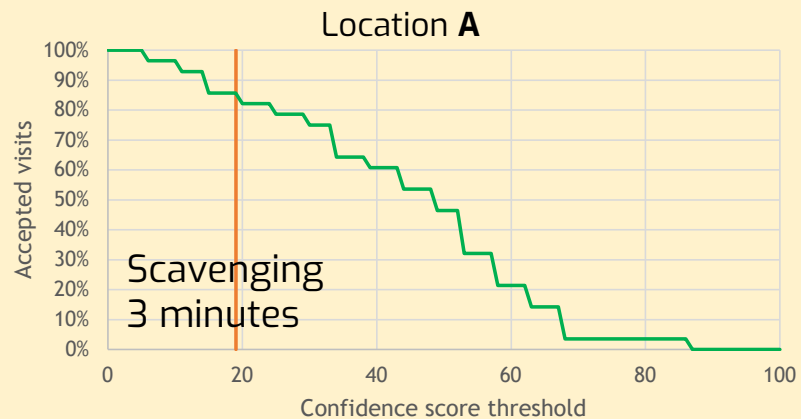


Results: Location detection performance

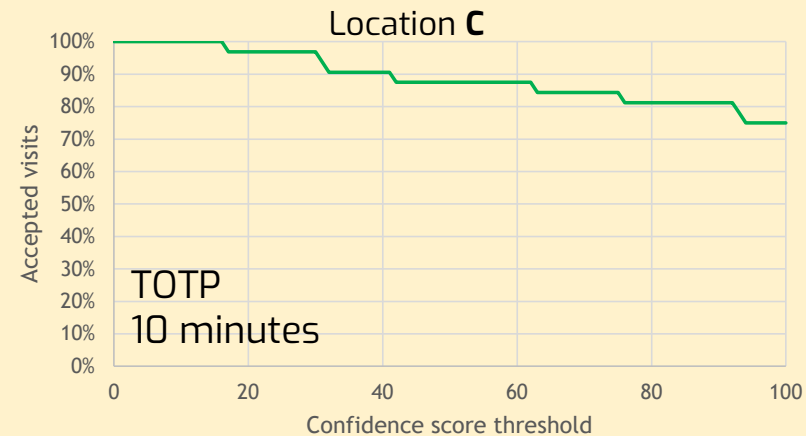
After 3 minutes at each location

Location	Proof Strategy	Total visits	Total detections	Success rate
A	Scavenging	34	30	88%
B	Scavenging	34	33	97%
C	TOTP	34	34	100%
N (not visited)	Scavenging	0	0	100%

Results: Location proof performance





% of seen APs



% of verified visit duration

Results: Power consumption

What is the power consumption of CROSS
vs. GPS?
vs. no collection?

Location collection method	Polling rate	Total test duration	Average battery drain	
CROSS using GPS + Wi-Fi	30 seconds	8 hours	1.25 p.p. / hour	 GPS usage has noticeable impact  Negligible impact
CROSS using Wi-Fi (as designed)	30 seconds	39.5 hours	0.61 p.p. / hour	
No collection	N/A	29.5 hours	0.58 p.p. / hour	

(p.p.: percentage points)

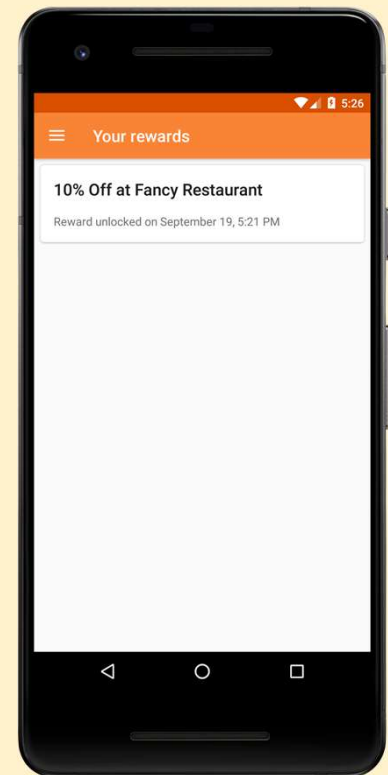
Results: Scavenging feasibility

- Are there enough Wi-Fi networks for scavenging to work?
- Does the network list require constant updates?

Wi-Fi networks present at urban locations in Lisbon					
Location	Initial total	After ten days		After one month	
		Present	New	Present	New
Alvalade	86	74 (86%)	13	73 (85%)	31
Pr. Comércio	133	8 (6%)	60	7 (5%)	43
Gulbenkian	80	54 (68%)	92	54 (68%)	55
Jerónimos	148	34 (23%)	100	24 (16%)	62
Oceanário	39	22 (56%)	41	24 (64%)	40
Sé	61	25 (41%)	43	22 (36%)	44

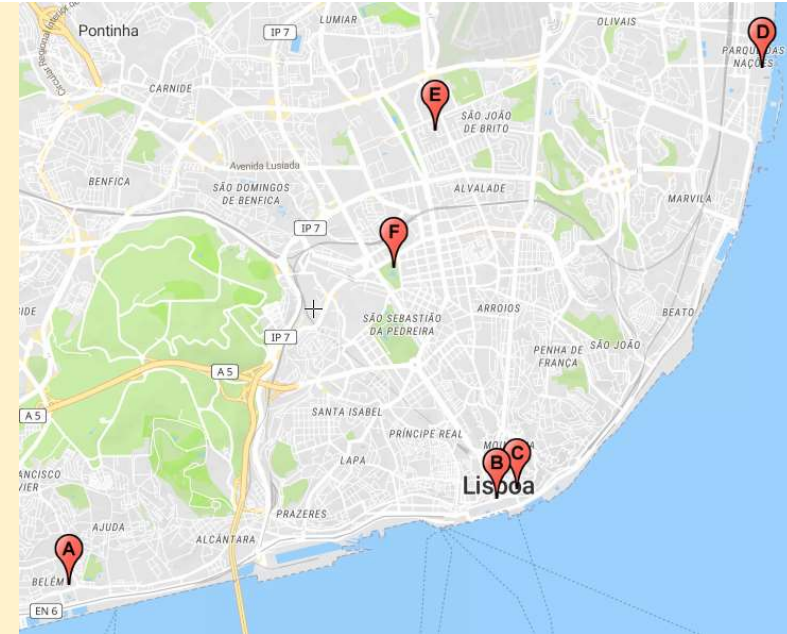
In conclusion, **CROSS**

- **Location proofs** in a smartphone application
 - Smart tourism – the **demonstrative** use case
- Three different location proof techniques
 - Nonintrusive **user experience**
 - Adequate **security guarantees**
- Can be extended
 - Other location proof techniques
 - Integration with third-party systems



Ongoing Work

- **Wi-Fi traces** scavenged provide new opportunities
 - Compiled these traces into a **dataset**
 - Of various points of interest in the city of Lisbon
- **Extend** the **scavenging** method of **CROSS**
 - To provide time-bound location proofs
- Use the diversity of **Wi-Fi networks** observed in the **dataset**
 - **Stable** networks (trigger) to determine location
 - **Volatile** networks (hotspots) to determine time window





Thank You

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Gabriel Antunes Maia

gabriel.maia@tecnico.ulisboa.pt

Presenter: Rui Nuno Lopes Claro

rui.claro@tecnico.ulisboa.pt

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Elsevier Journal on Pervasive and Mobile Computing
Special Issue on "Location Based Services and Applications in the era of Internet of Things"