



ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ  
ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΡΗΤΗΣ

# Ασύρματα Δίκτυα και Κινητοί Υπολογισμοί

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Τμήμα Επιστήμης Υπολογιστών  
Πανεπιστήμιο Κρήτης

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- Το παρόν εκπαιδευτικό υλικό έχει αναπτυχθεί στα πλαίσια του εκπαιδευτικού έργου του διδάσκοντα.
- Το έργο «**Ανοικτά Ακαδημαϊκά Μαθήματα στο Πανεπιστήμιο Κρήτης**» έχει χρηματοδοτήσει μόνο τη αναδιαμόρφωση του εκπαιδευτικού υλικού.
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- Ως **Μη Εμπορική** ορίζεται η χρήση:
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- Ο δικαιούχος μπορεί να παρέχει στον αδειοδόχο ξεχωριστή άδεια να χρησιμοποιεί το έργο για εμπορική χρήση, εφόσον αυτό του ζητηθεί.

# Supporting Wireless Access Markets with a User-centric QoE-based Geo-database

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Nikolaos Rapousis

Under the supervision: Maria Papadopouli



# Roadmap

- Motivation
- Related work
- U-map system
- Modeling and simulation
- Conclusions and future work

By 2014 mobile data traffic over 3.6 exabytes/month worldwide  
Spectrum: a scarce resource of high economic value (~1 trillion USD)  
Constraints due to traditional spectrum allocation

Shannon's law sets the limits on the achievable transmission rate

Technological advancements on spectral efficiency

- MIMOs
- Intelligent & directional antennas
- Channel assignment, topology control, MAC protocols
- Cognitive radio networks (CRNs)

 New access markets & service paradigms & architectures

# Paradigm shift in wireless access markets

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*"I'm afraid you've had a paradigm sbift."*

## Traditional cellular markets

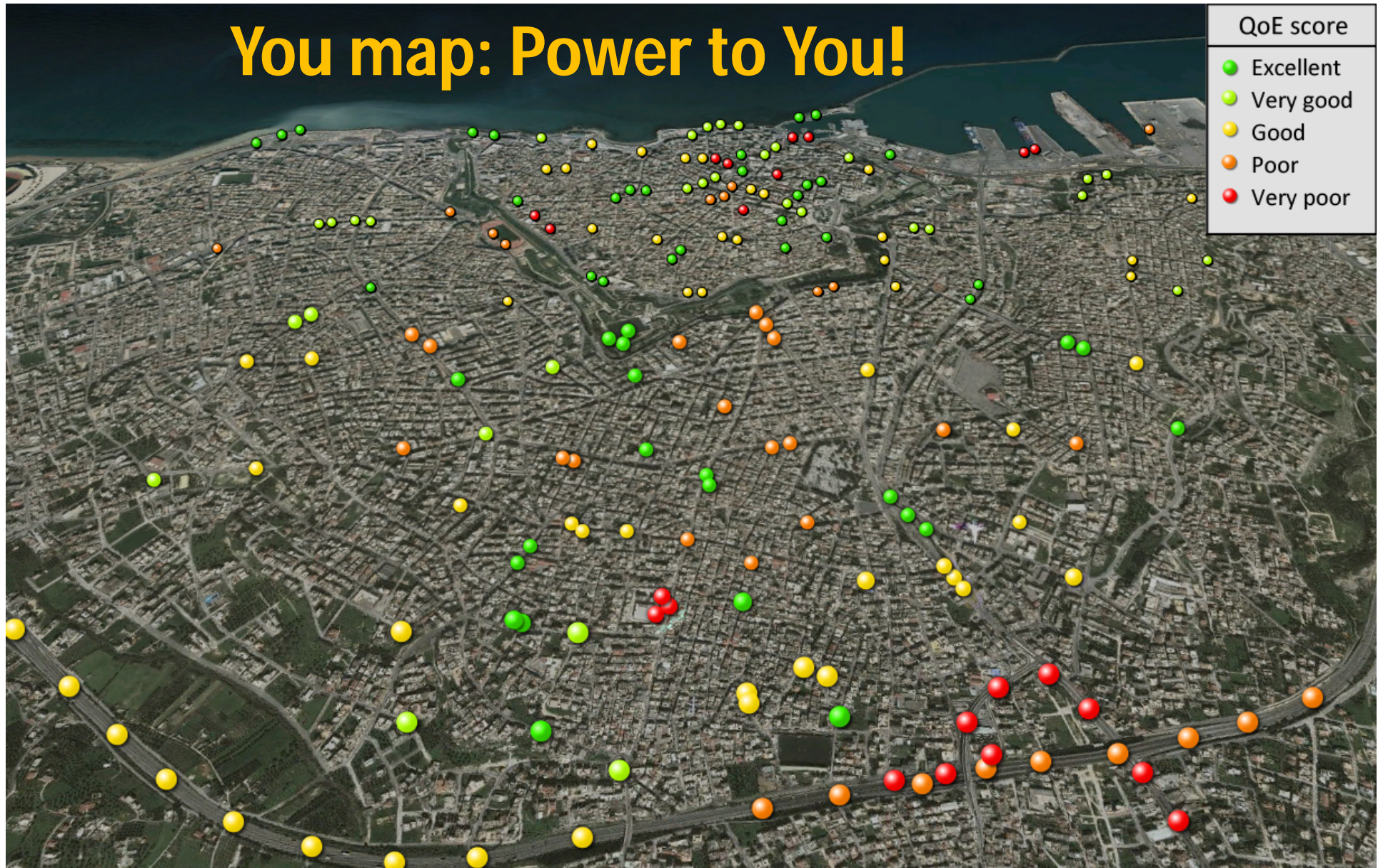
- **Long-term licenses** with exclusive access rights
- Client is **associated** with **certain provider**
- **Long-term customer subscription**

## New wireless access markets

- **Larger sizes** in number of clients & providers, data rates, demand
- More **heterogeneous & diverse** in populations, services, preferences, deployments, environments
- More **complex** (e.g., spectrum allocation, infrastructure, pricing/billing, QoE)
- **Coalitions** among providers on information, services, infrastructure (MVNOs)
- Open spectrum, spectrum DB, grass-root efforts, crowdsourcing
- **Multiple scales**

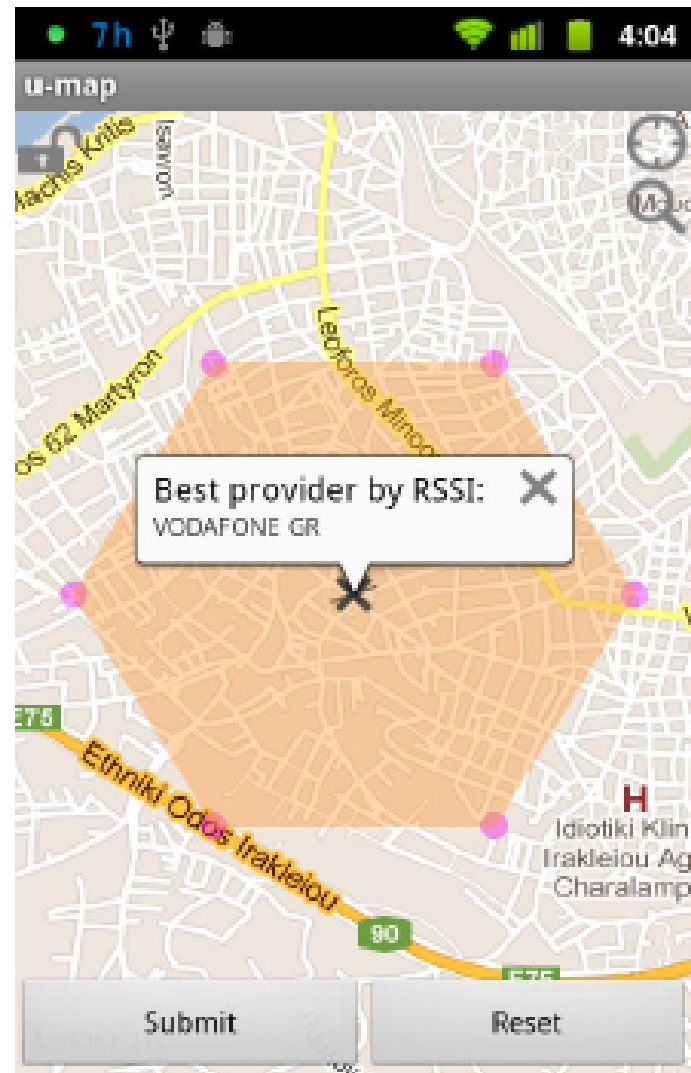
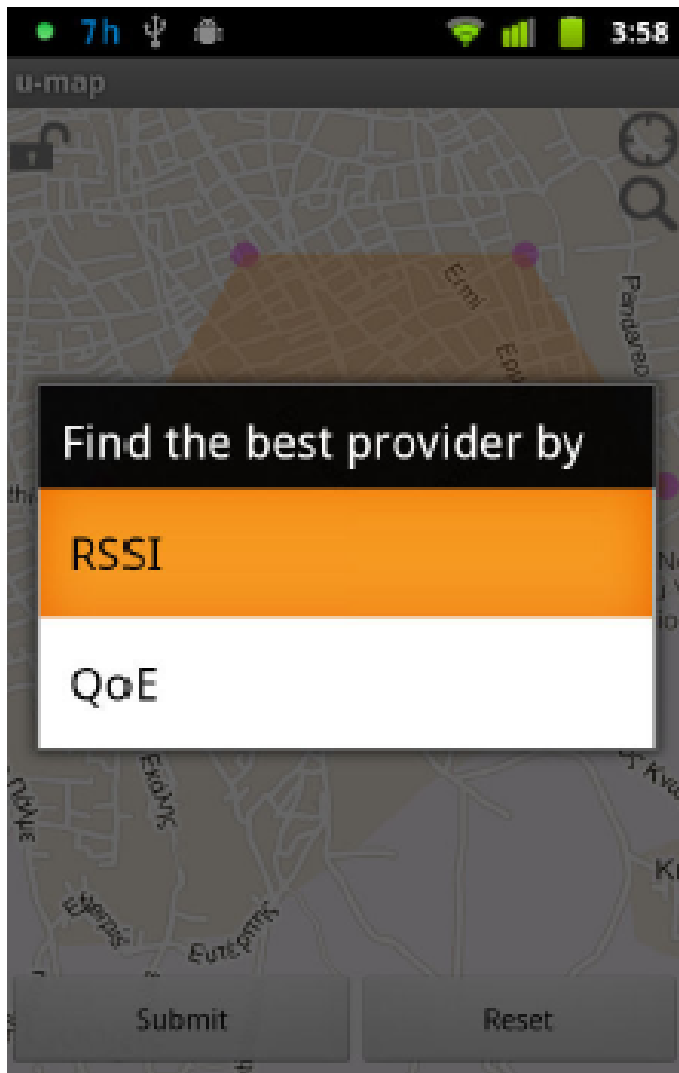


# You map: Power to You!



{u-map: a user-centric QoE geo-database, feedback system.}





## 2.2.2. [REDACTED] Boosting consumer choice and protection

All stakeholders in general support a broader focus on more empowerment of end users. Some of them believe that well informed [REDACTED] of suppliers will enable a [REDACTED] benefit of consumers and industry. In that aspect all contributors pay great attention to the transparency especially in the context of bundled offers and net neutrality measures. [REDACTED] that respect several of the stakeholders think that BEREC should further work on avoiding the unjustified traffic management practices, stressing that measures taken out of commercial motivations might lead to discriminatory practices with a direct negative effect towards the consumers.

Despite the general support for strengthening the consumer protection, some of the stakeholders point out that consumer protection measures should complement and not supersede the legal framework for competition. One of the stakeholders is of the opinion that BEREC should not adopt decisions in the field of privacy and data protection in order not to cause confusion and legal uncertainty.

## 2.2.3. Service related developments

In its draft Strategy BEREC has envisaged undertaking additional work in the field of international roaming, net neutrality, special rate and/or cross-border services, mainly through developing common concepts [REDACTED] and will focus on the elaboration of better methodologies to ensure comparability of data with a view to ensuring better and monitoring.

In addition the stakeholders propose BEREC to undertake additional measures, as follows:

- In the field of international roaming - to work more in order to guarantee development and growing of competitive alternatives [REDACTED]
- In the fields of net neutrality and transparency, including quality of service - to [REDACTED] access),
- In the field of cross-border services – dedicating more efforts to facilitating their provision, including through dissemination of the best practices existing in that field.

# { u-map: user-centric QoE geo-database. }

## Client-to-Server architecture

- **u-map clients** on mobile devices
    - Collect network measurements and store them locally
    - Upload traces to the u-map server
    - Query the u-map server
  - **u-map server**
    - Collects traces & stores them in **spatio-temporal** geo-DB
    - Responds to queries sent by users, providers, regulators
- ☞ Can be designed according to different **business models**
- grass-root service
  - operator-driven
  - third-party/provider
- Under appropriate **access control & privacy rules**
  - Provision of **incentives**
    - reputation, altruism,
    - payment (e.g., free SMS, calls)



**Query** for the best provider in a region



**Upload** network & QoE measurements

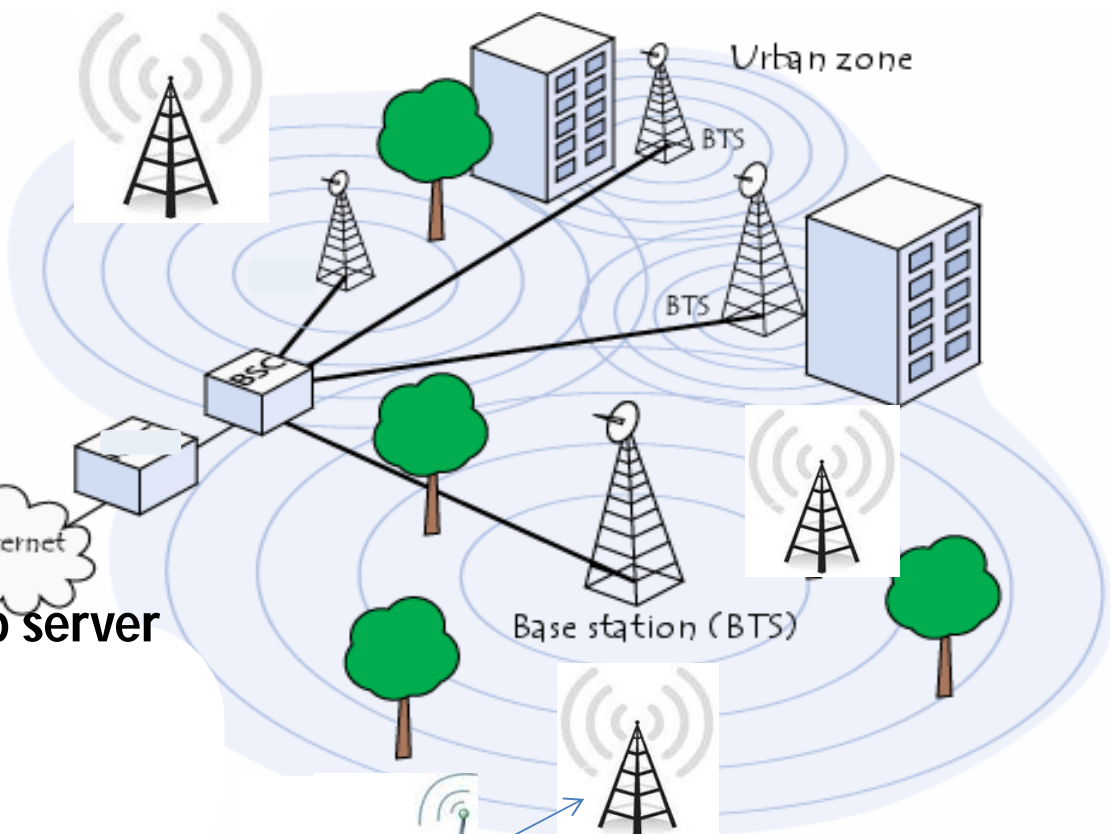


**u-map client**



**u-map server**

Internet



Urban zone

BTS

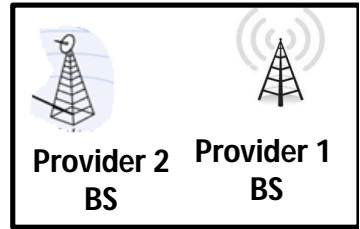
BTS

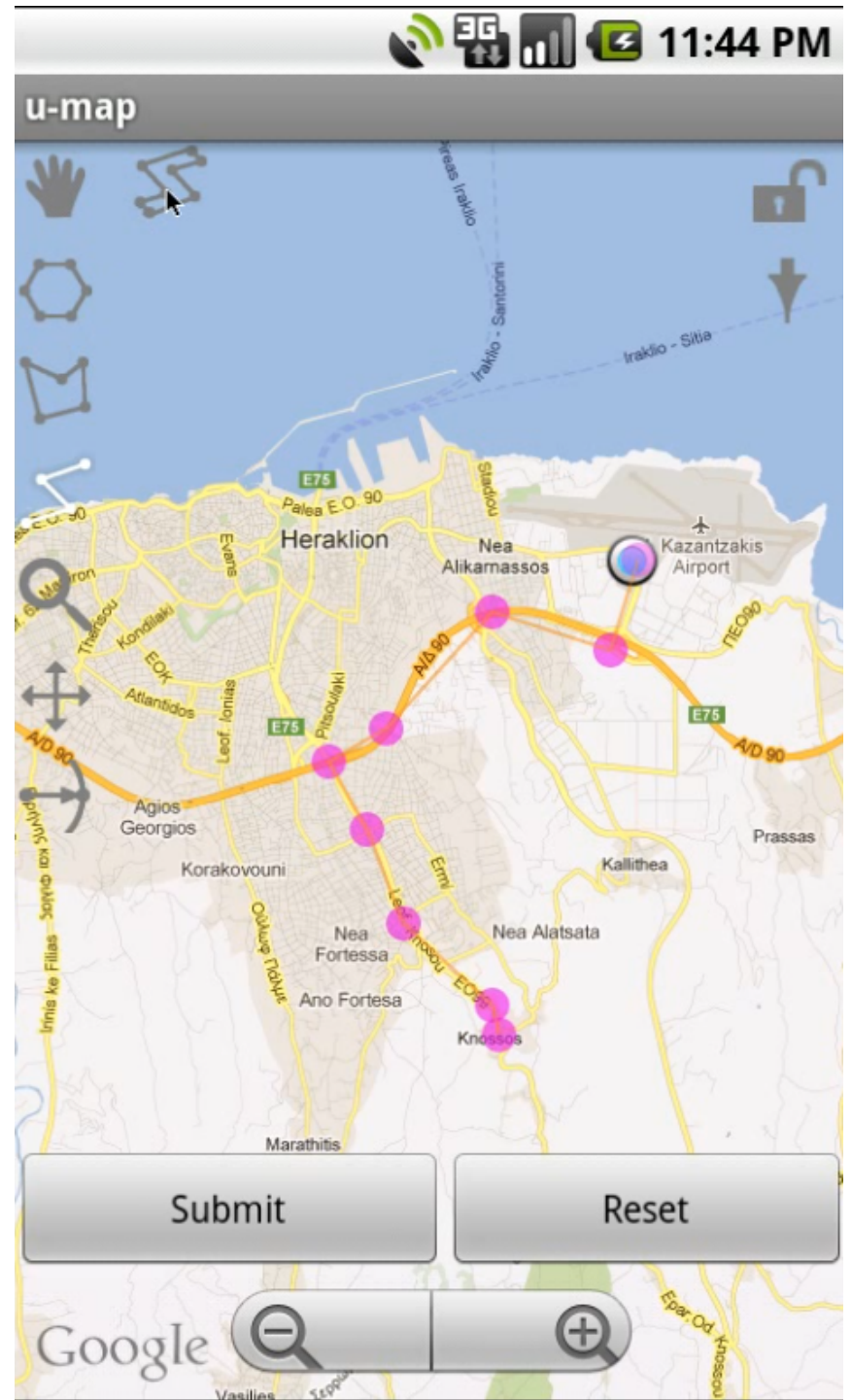
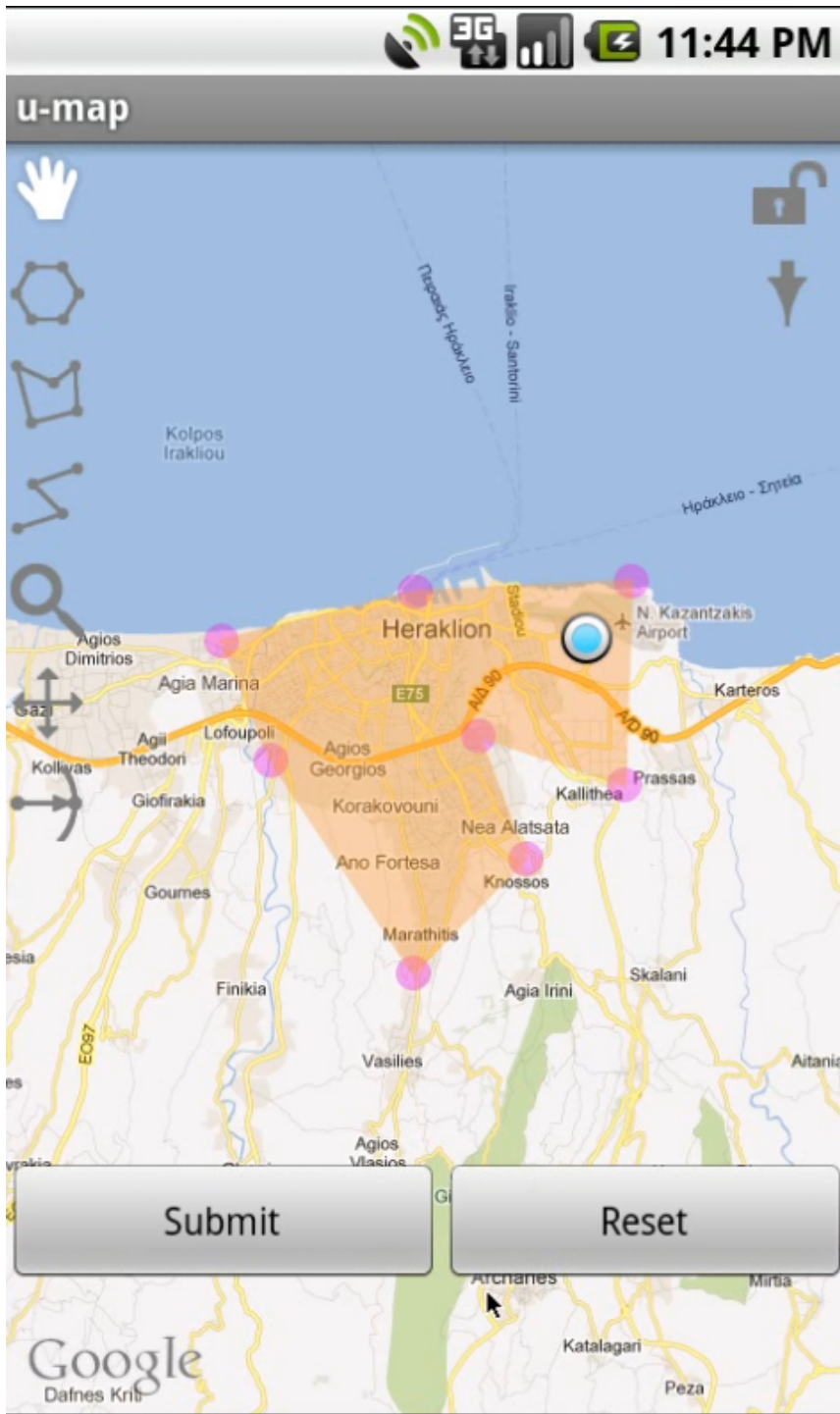
Base station (BTS)

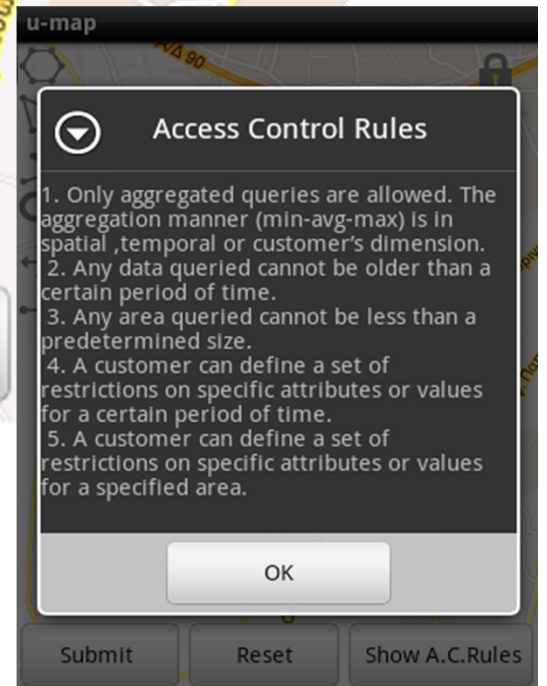
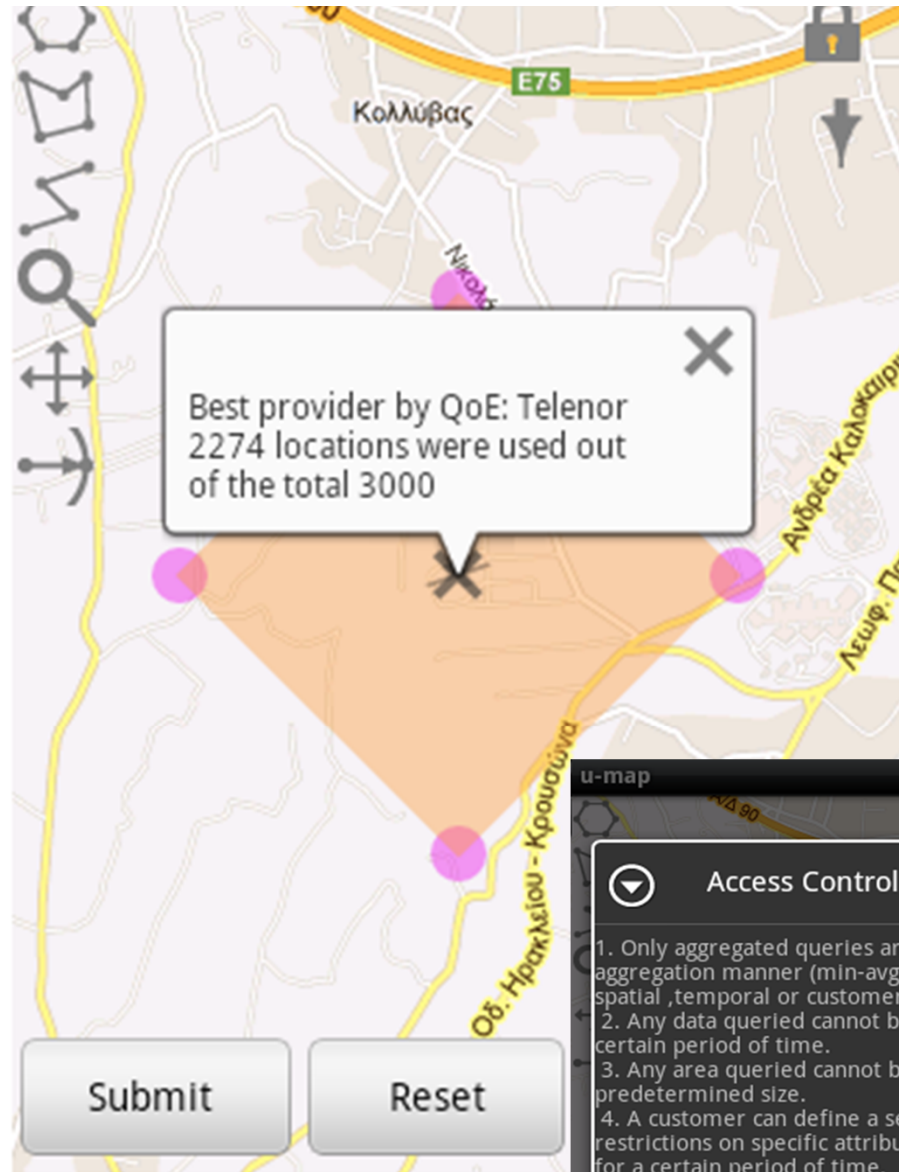
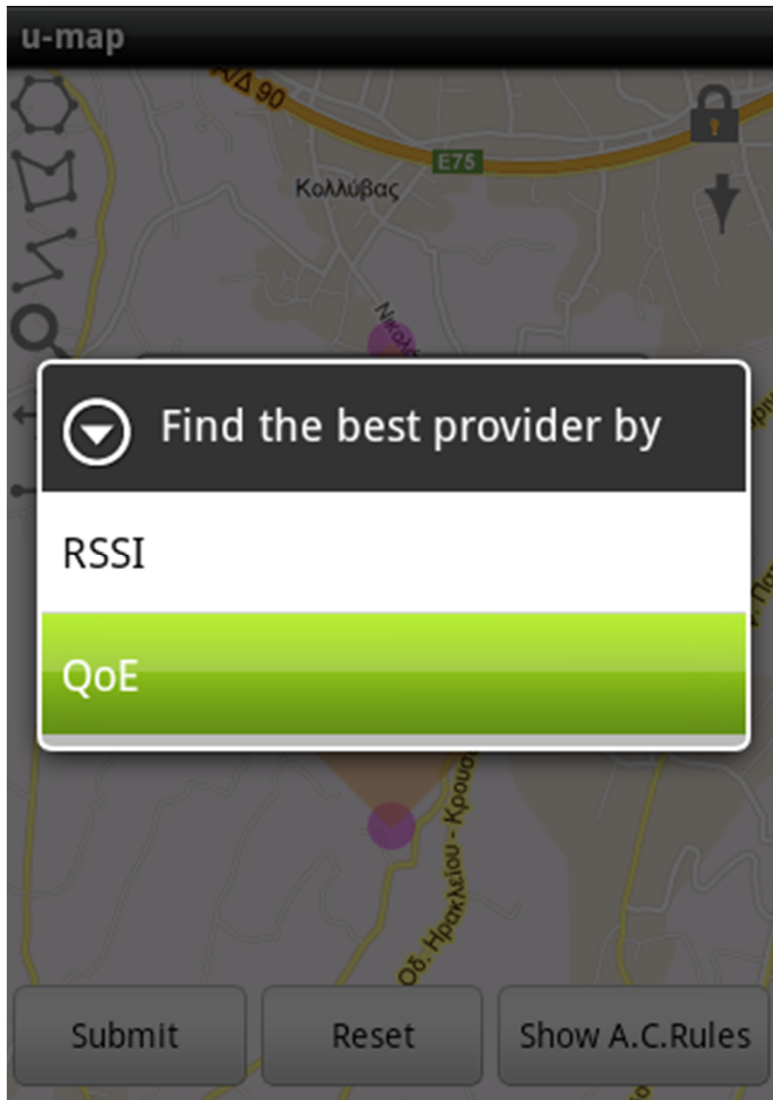


**Providers** query about network condition, coverage, customers

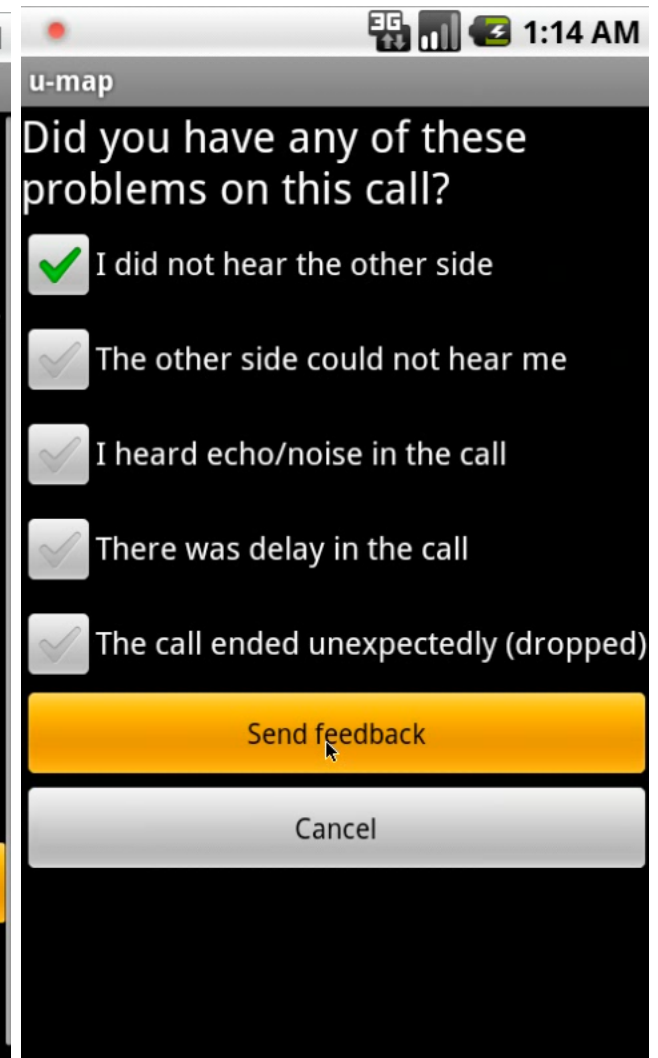
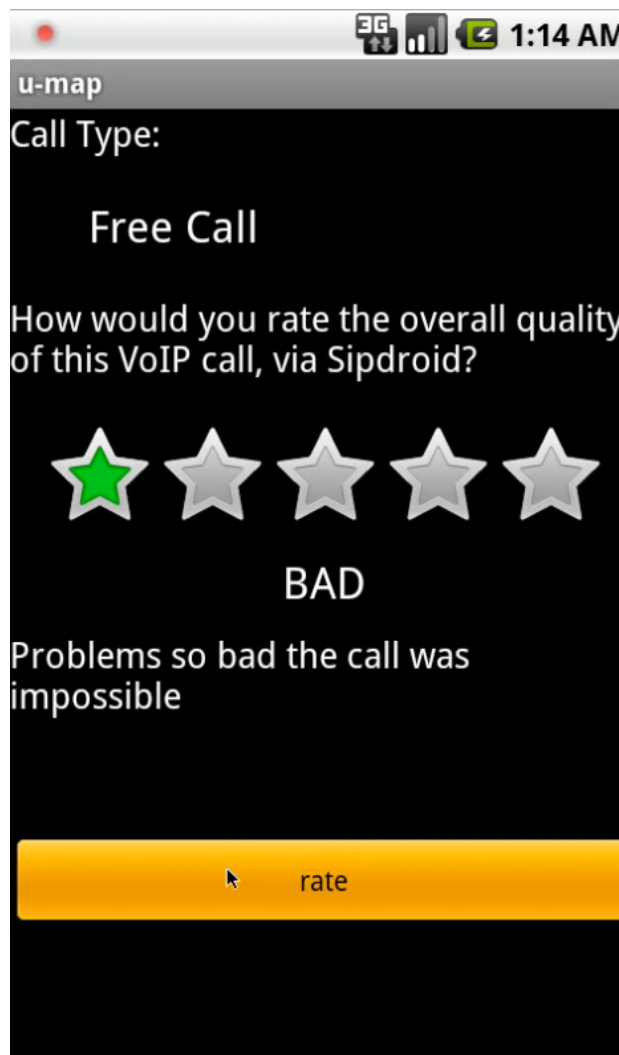
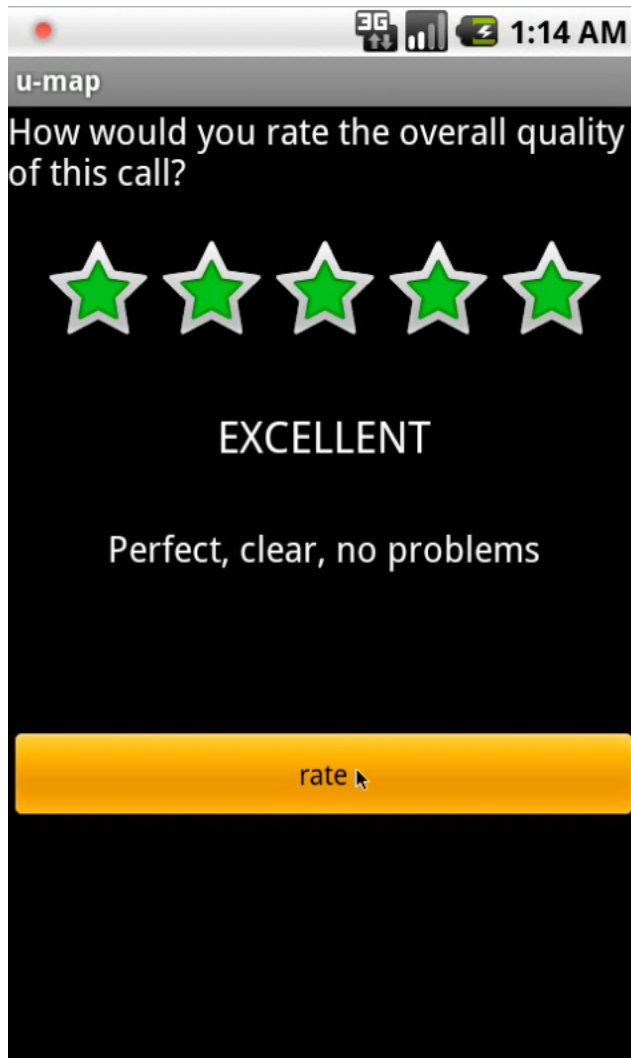
**Regulators** query about coverage of providers



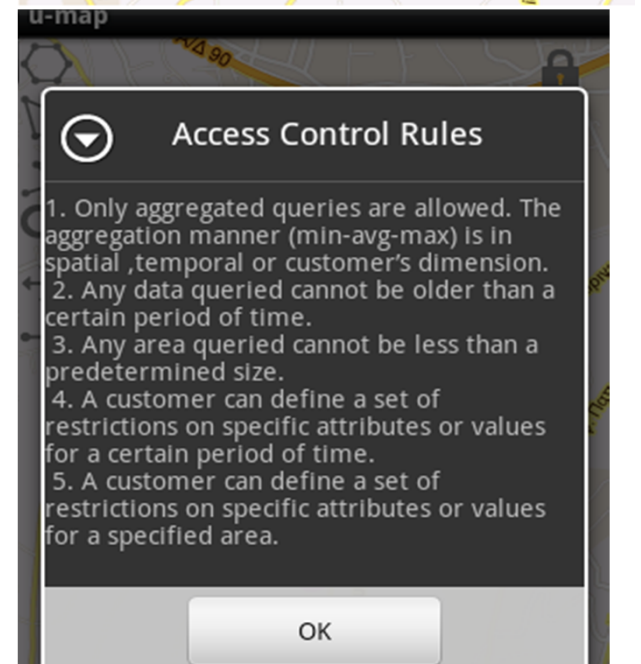
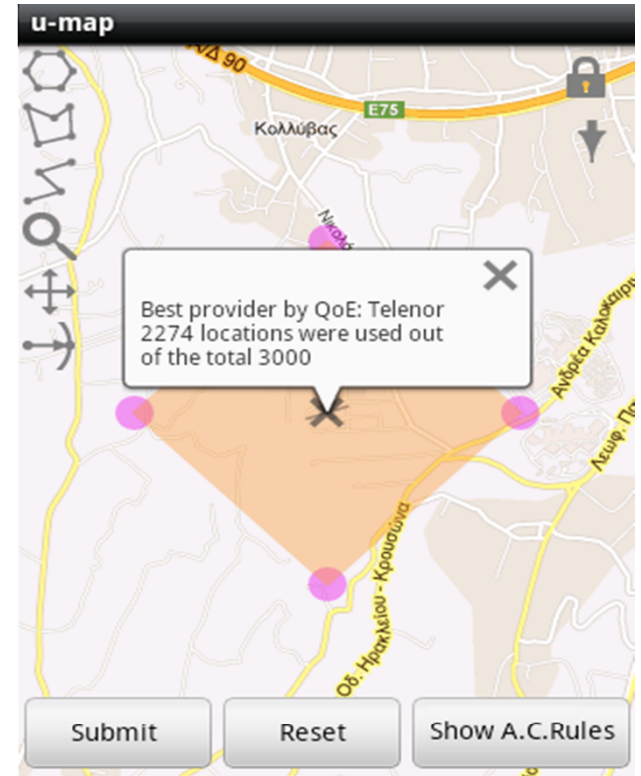
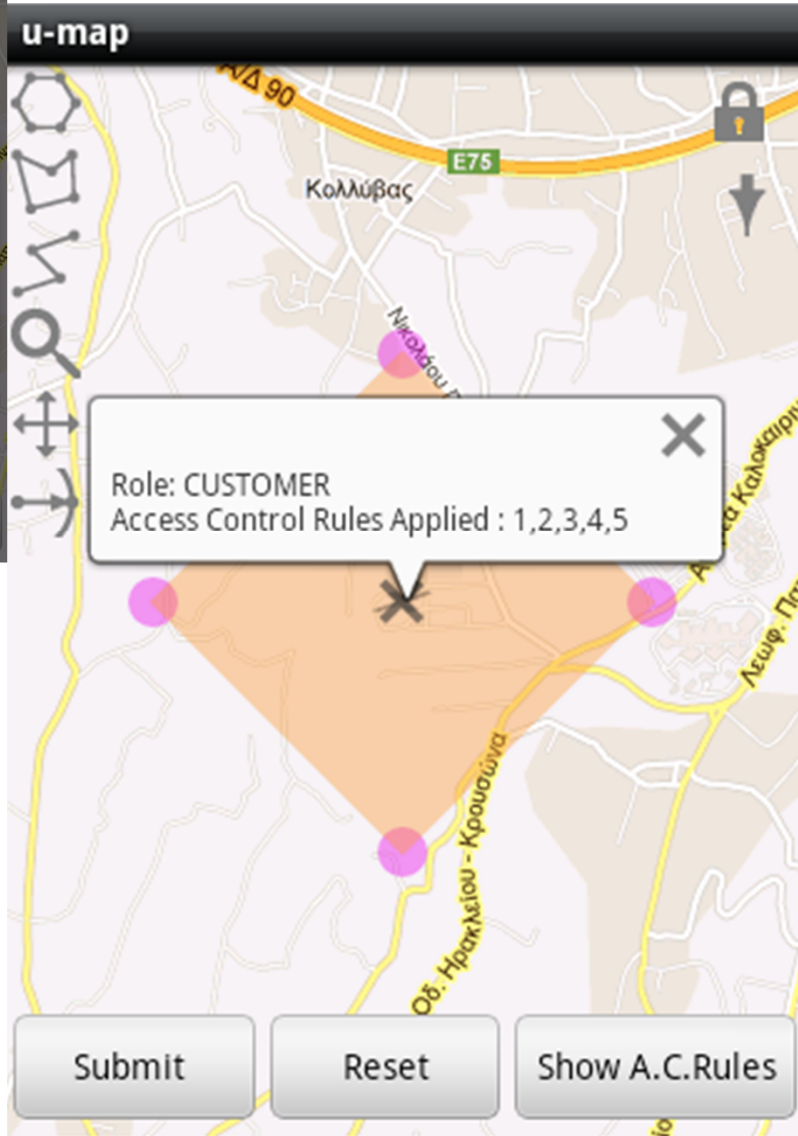
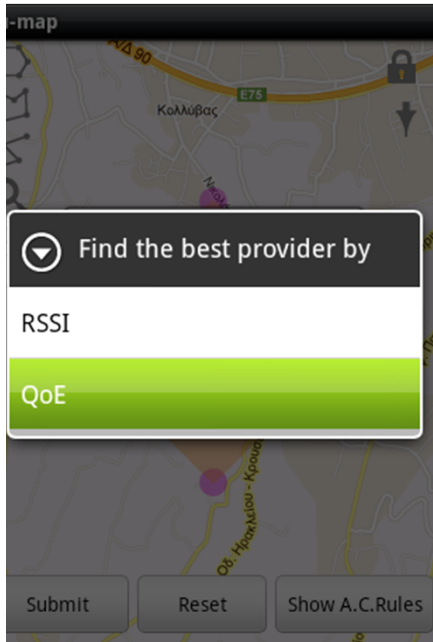


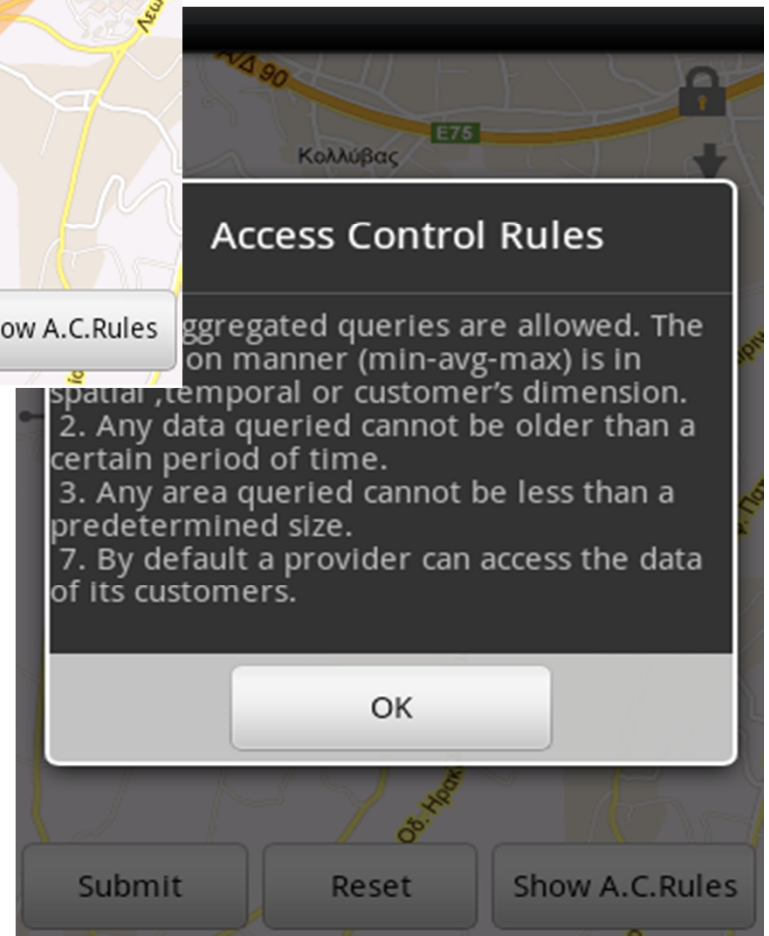
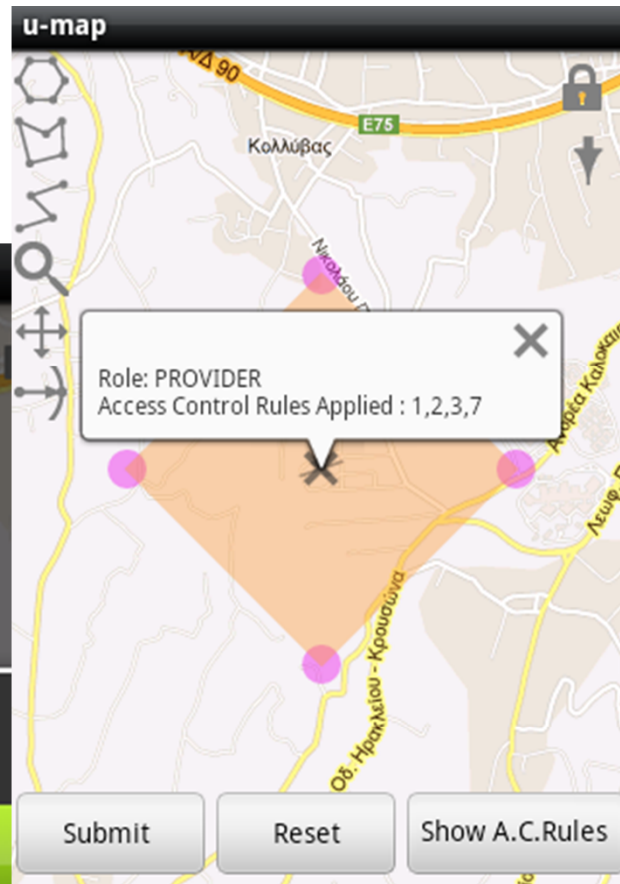
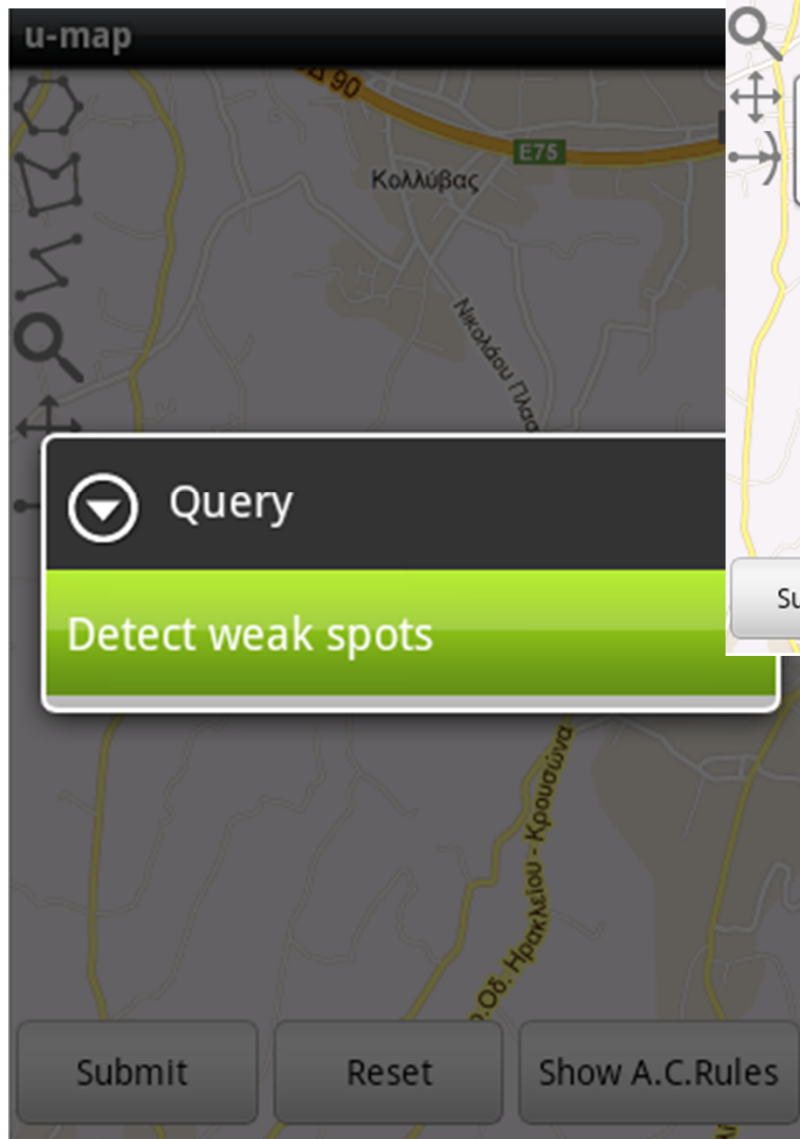


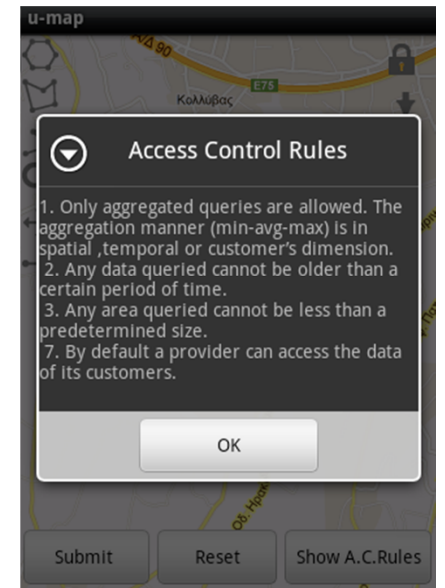
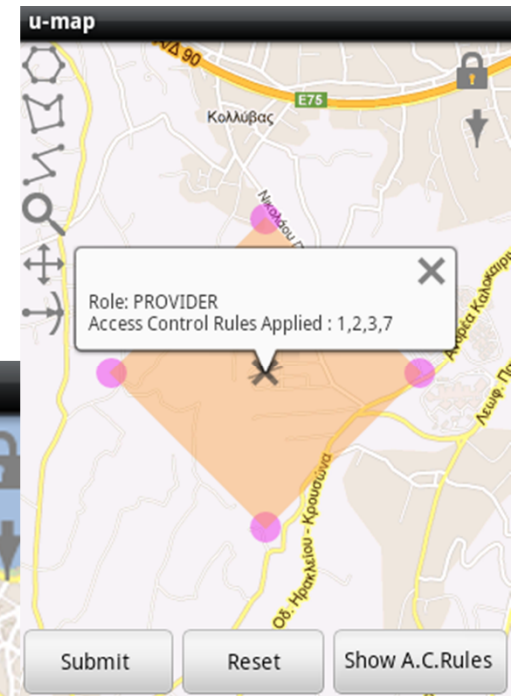
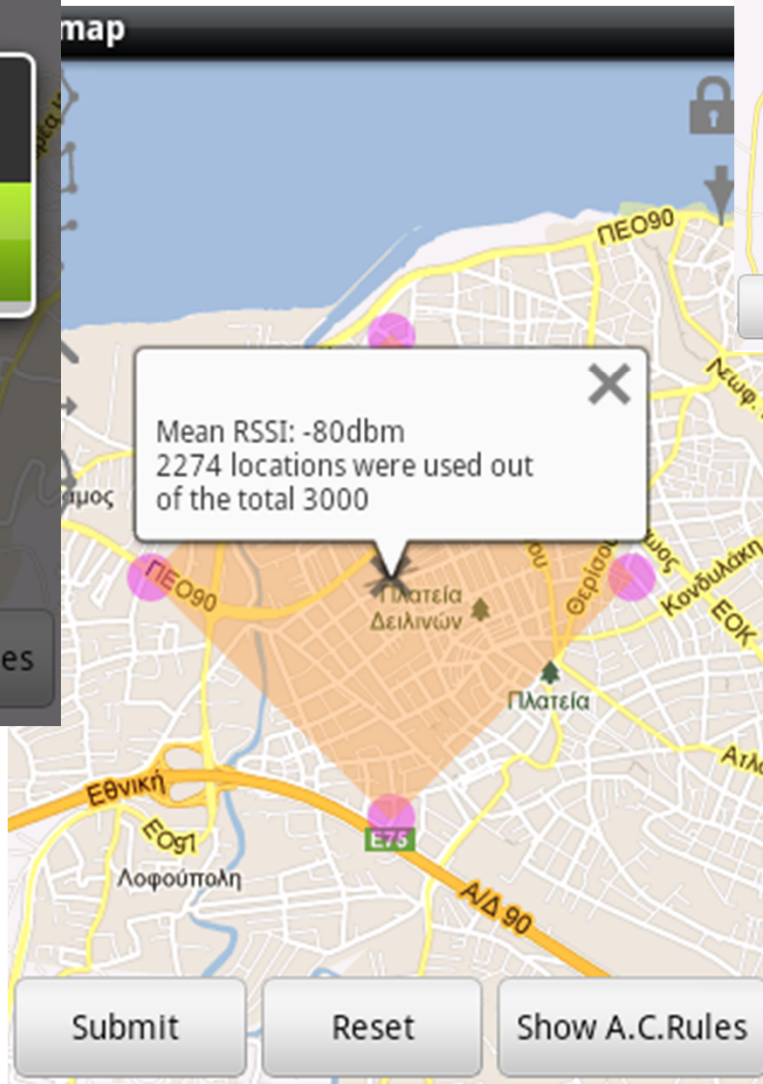
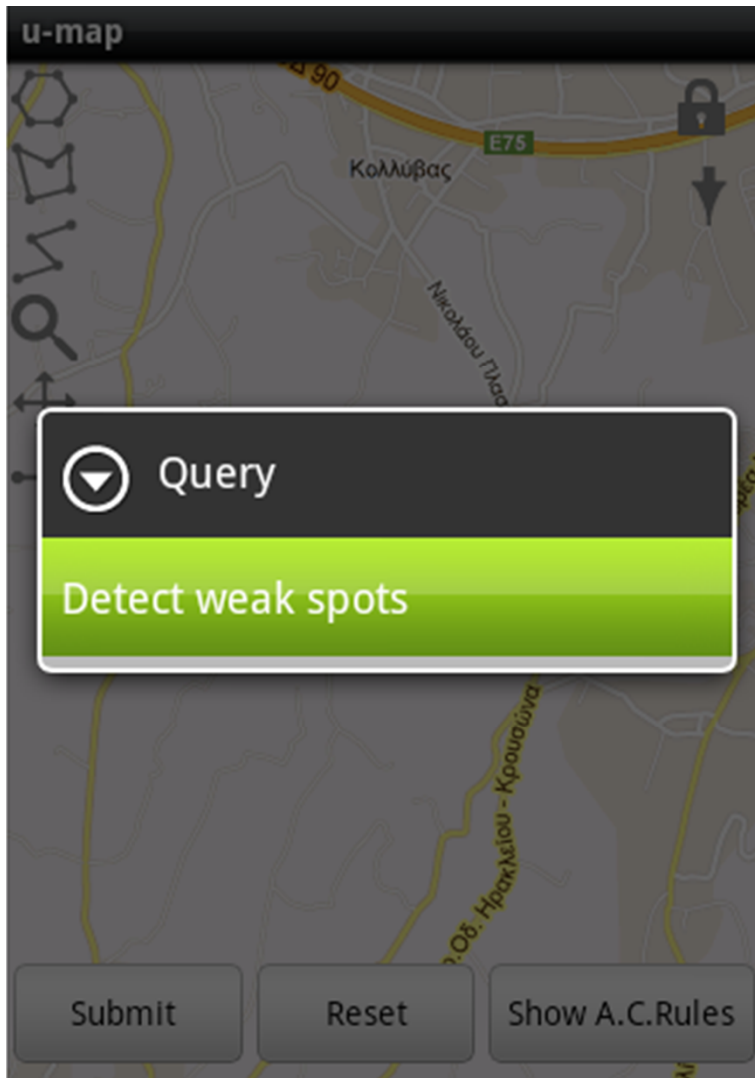
# Evaluating services, reporting problems, sharing experience.











# Via the u-map, an operator can learn its strengths & weaknesses, adapt, & evolve.

**Customer profiling**, clustering ...

**Technical: QoS & QoE** issues ...

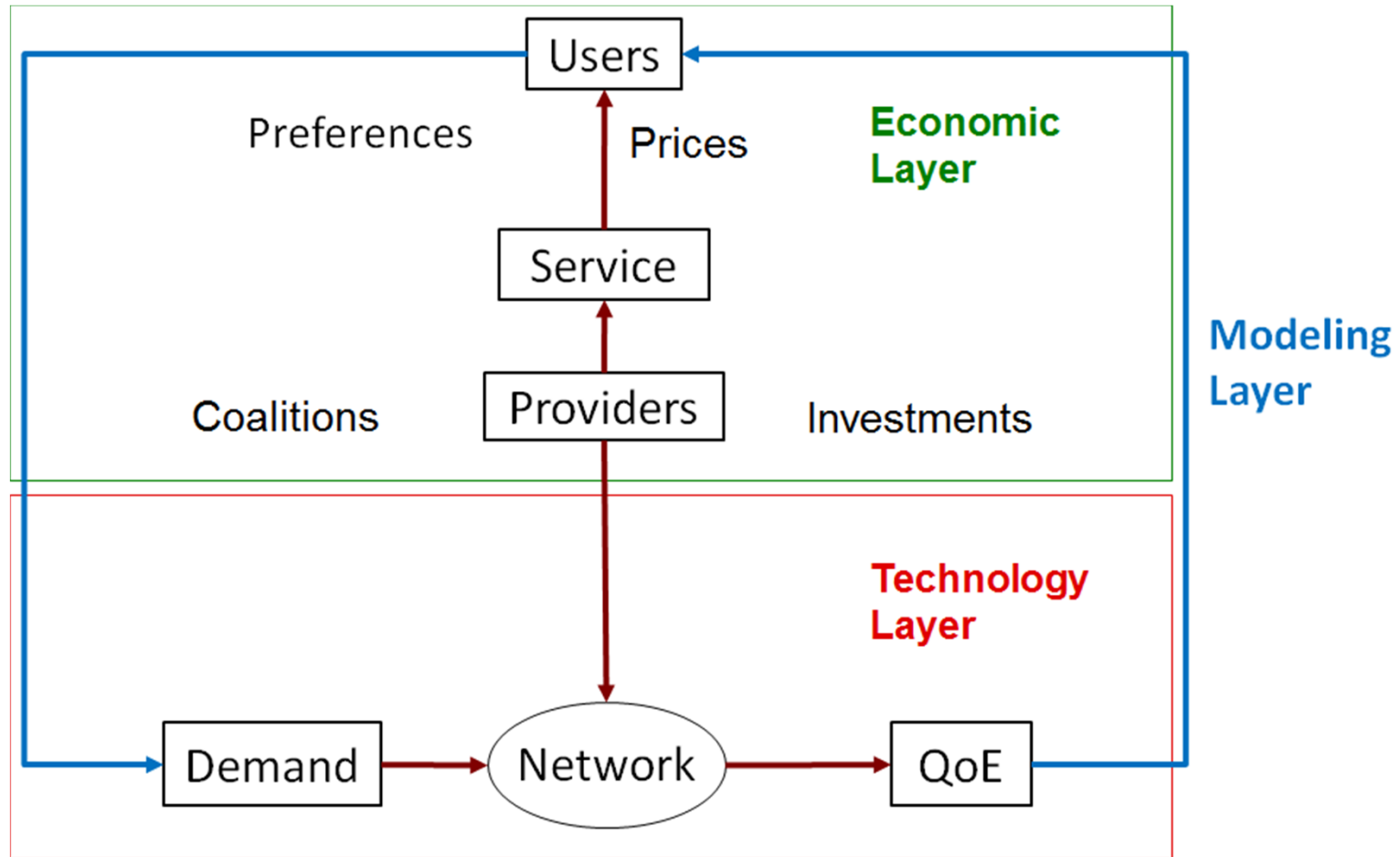
**Business:** marketing, **pricing**, strategy, ...

**advertise its performance**

**Transparency:** the “**good operator**” model



Based on the requirements for realism, accuracy, scalability, model the entities at the appropriate scale.



[Ref. diagram by Walrand. ]

# Motivation

- **Customers** perform **educated selection** of appropriate provider
  - Improve wireless access
- **Providers** are **aware** of user opinion for their services
  - Enhance capacity planning, design appropriate services
- **Regulators** analyze **network measurements**
  - Check if providers/customers comply with spectrum access rules

# Main contributions

- Develop **u-map**, a geo-database with customer feedback on:
  - QoE of services
  - Traffic demand
  - User profile
  - Spectrum conditions
  - Position
- Introduce **flex service**: Users select provider/BS on a **per session** basis
- Develop modeling framework & simulation platform to assess impact of **u-map** and **flex service** on wireless access markets

# Related work (1/2)

## Databases with physical layer information:

- Open spectrum approach (Karlsson *et al.* [ACM CFI 10])
    - User feedback: Providers improve infrastructure/reduce interference
  - Geo-database for TV-bands (Gurney *et al.* [IEEE DySPAN 08])
    - Regulators correct interference problems
- ☞ U-map integrates **a richer set** of data
- **Cross-layer** measurements, **user** preferences and constraints

# Related work (2/2)

## Mobile phones sharing measurements:

- Micro-blog (Gaonkar *et al.* [ACM MobiSys 08])
  - Cameras, GPS, accelerometers, health monitors
- MyExperience (Froehlich *et al.* [ACM MobiSys 07])
  - Device usage, user context info, environmental measurements

☞ U-map aims to improve **wireless access markets**

# Roadmap

- Motivation
- Related work
- U-map system
  - Architecture
  - Testbed
  - Performance evaluation
- Modeling and simulation
- Conclusions and future work

# U-map

- Follows **client-to-server** architecture
- **U-map client:** Runs on mobile devices
  - Collects network measurements
  - Stores measurements in traces locally
  - Uploads traces to u-map server
  - Performs queries to u-map server to obtain information
- **U-map server:**
  - Collects traces from mobile devices
  - Stores traces in **spatio-temporal** geo-database
  - Responds to queries sent by users, providers, and regulators
  - Applies appropriate **access control** and **user privacy** rules

# Example of u-map

To start a **session**, select any BS of either provider in range

1. **Users** query u-map for the best provider in a region

2. Response to query

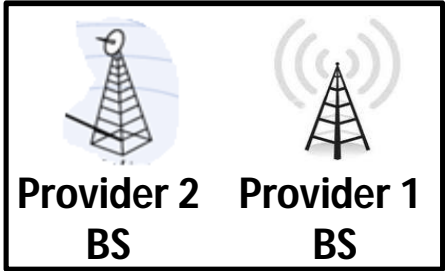
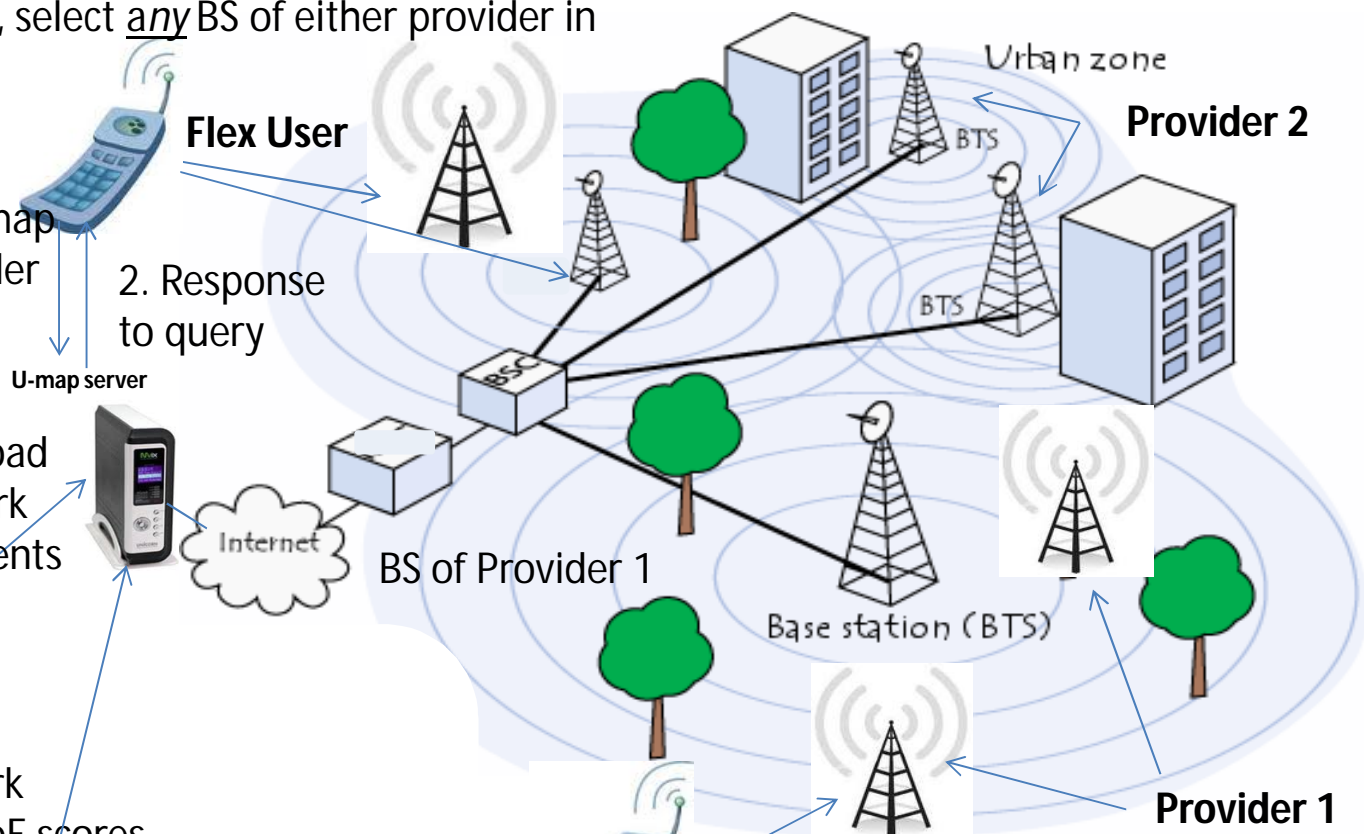
A2. Regularly upload traces with network & QoE measurements

## U-map client

A1. Record network performance & QoE scores locally

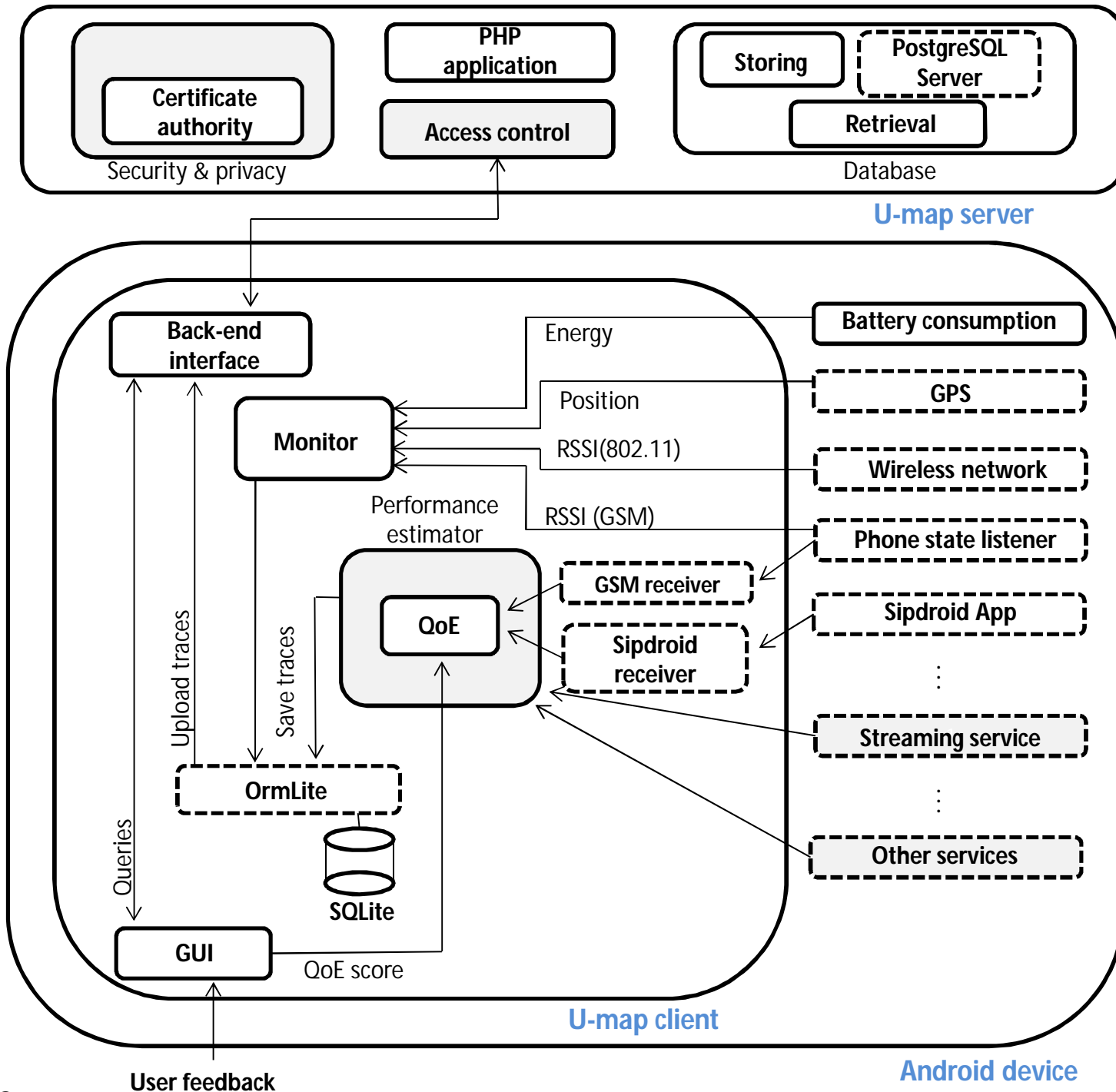
**Providers** query for their QoS & coverage in regions

**Regulators** query about QoS & coverage of various providers

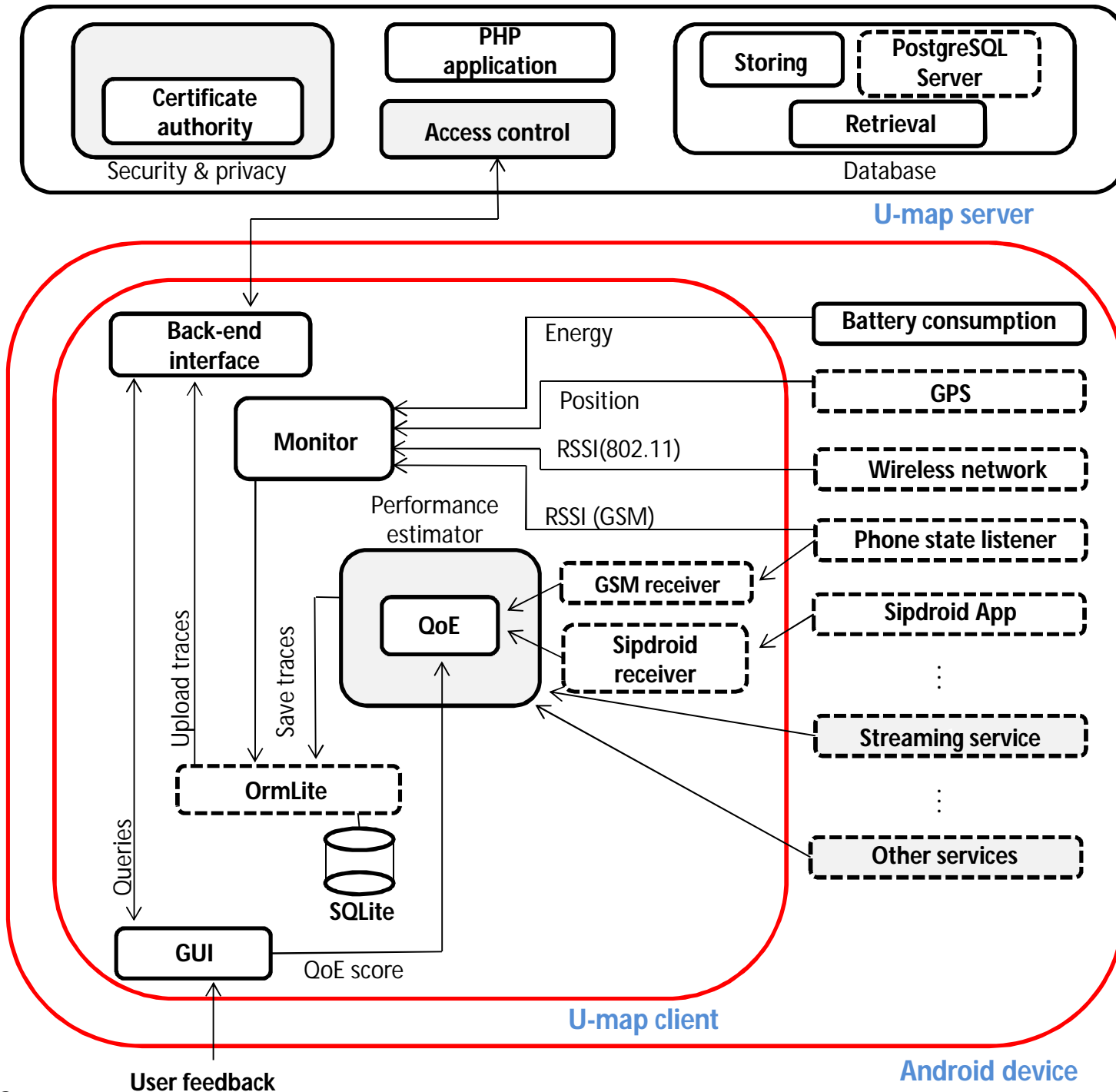




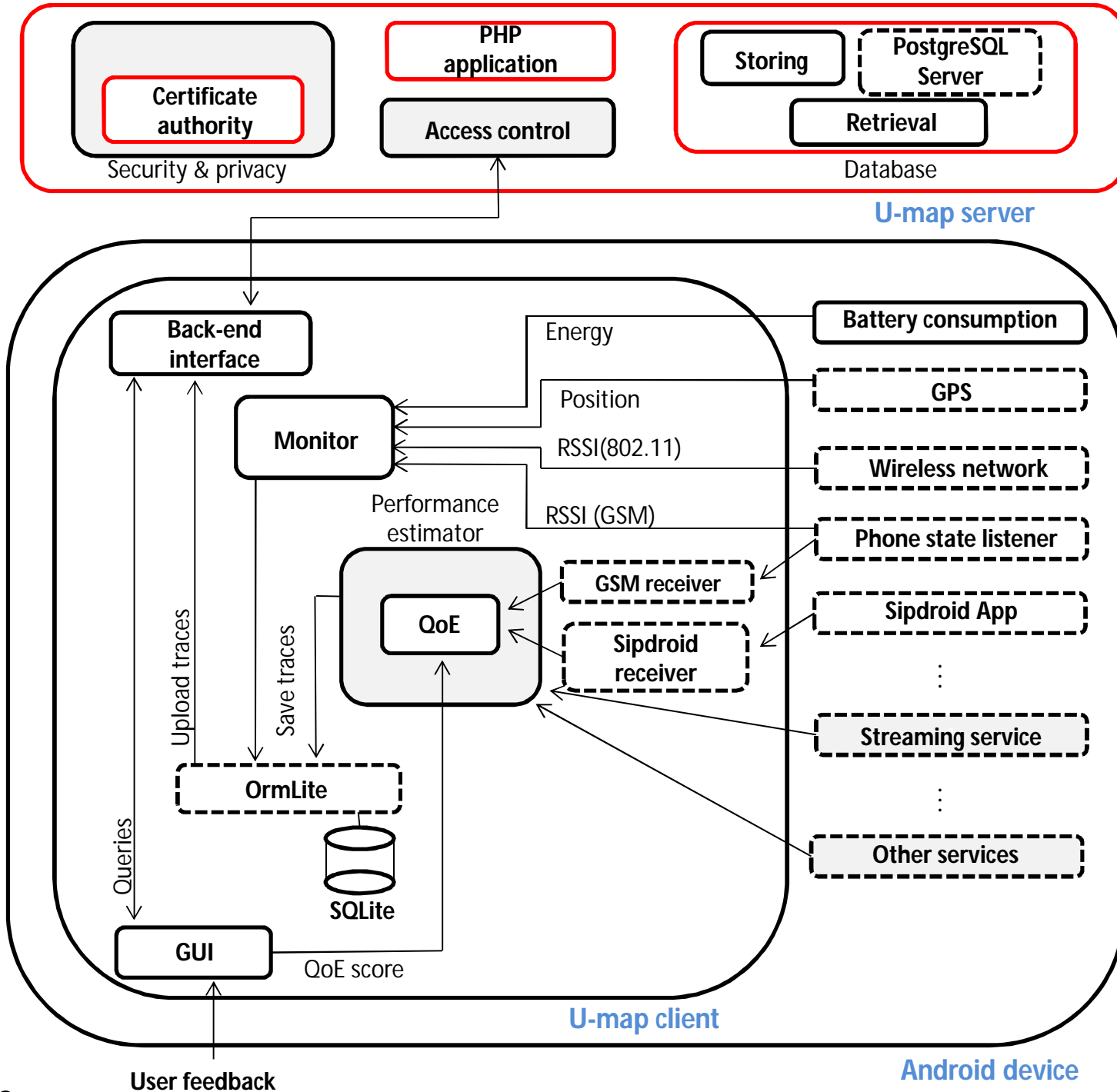
# U-map architecture



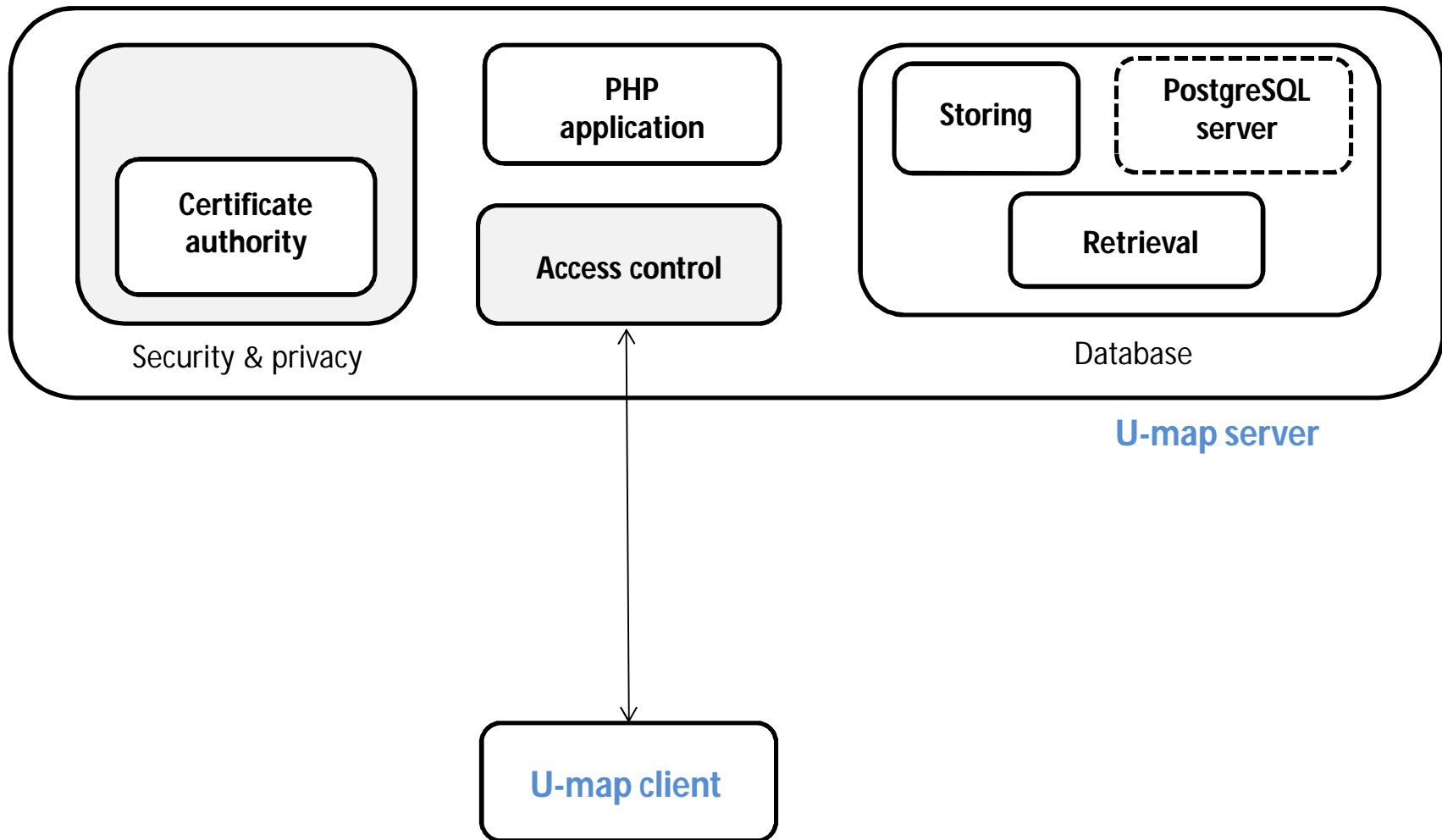
# U-map architecture



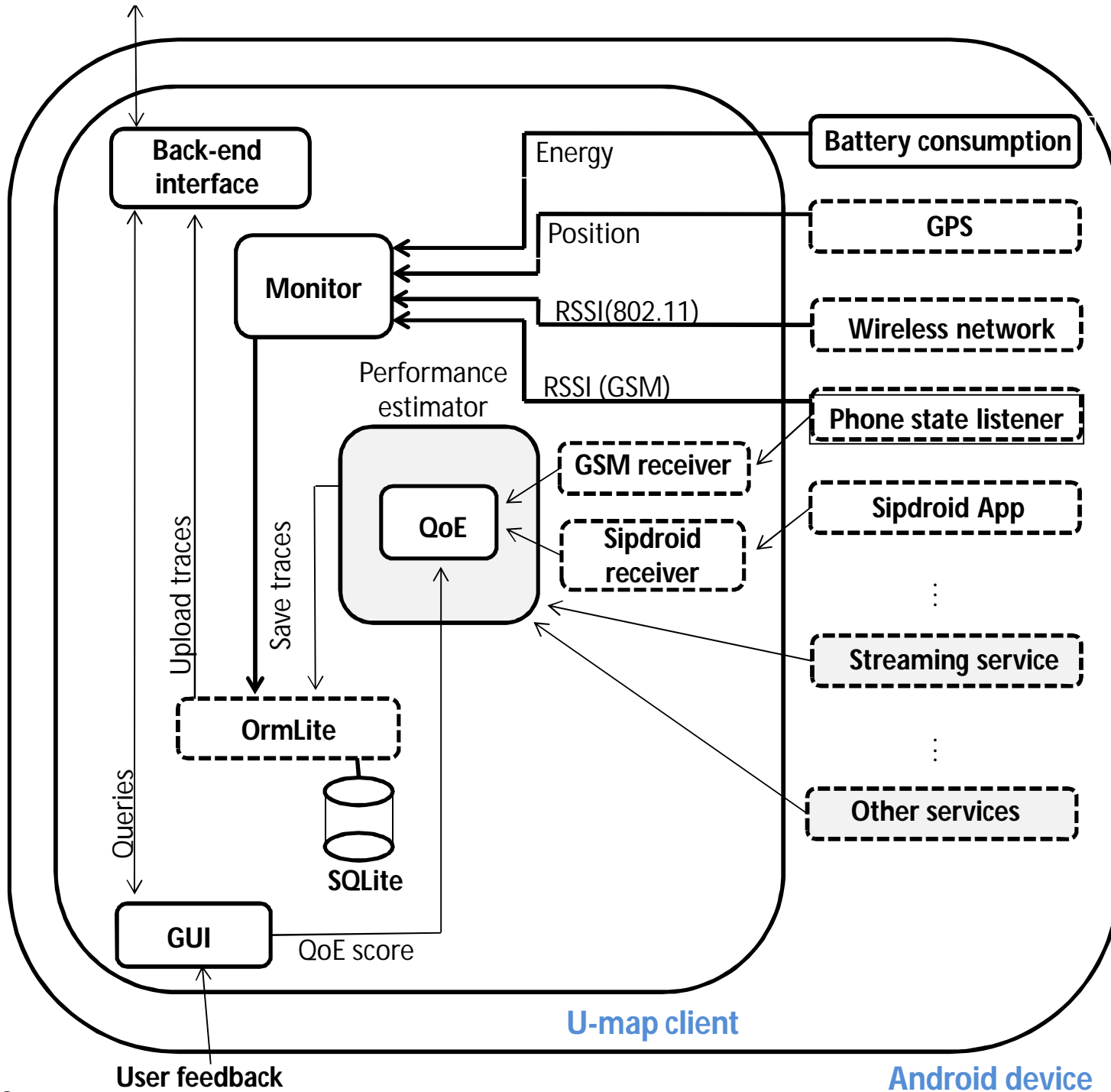
# U-map architecture



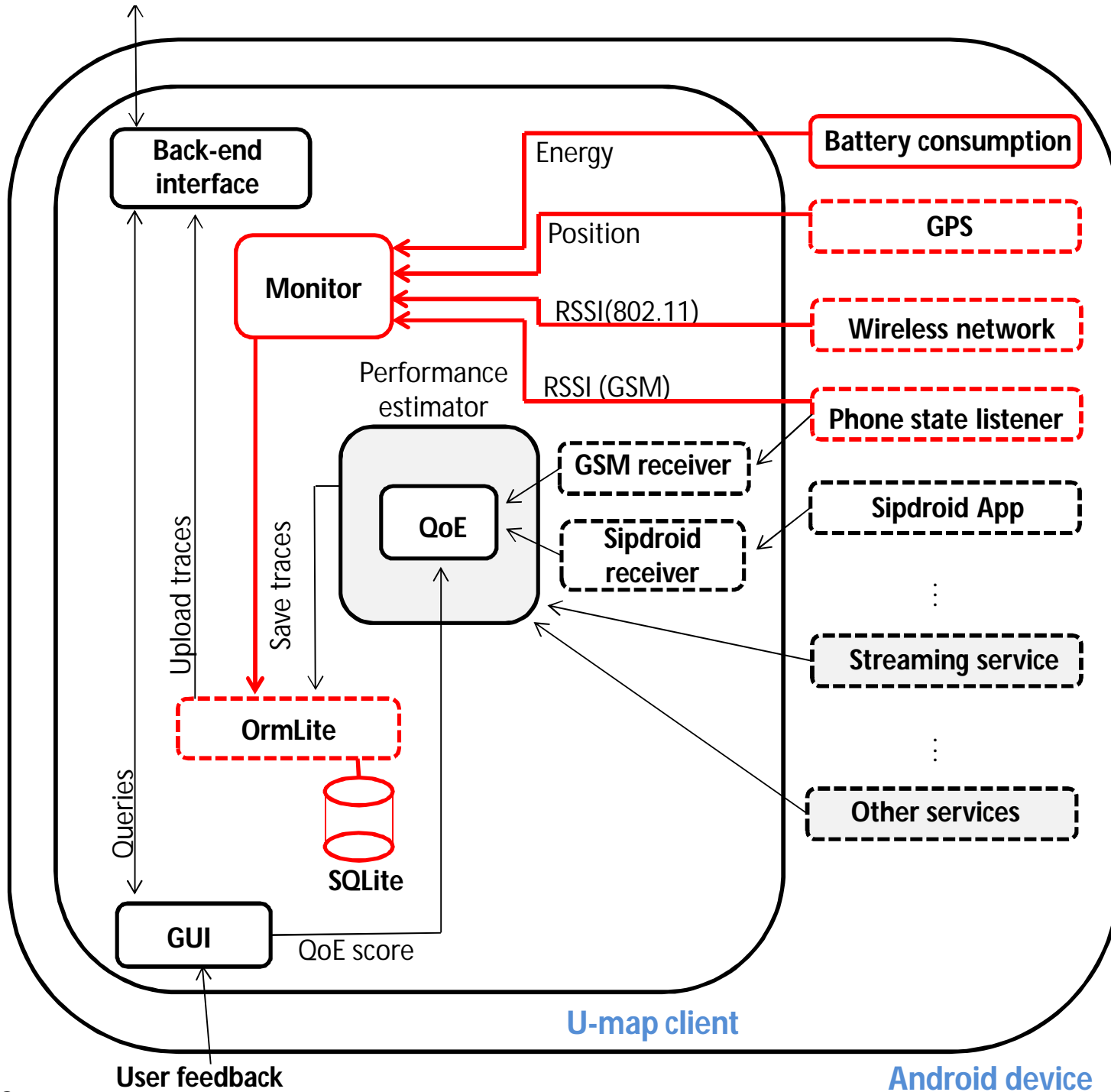
# U-map server



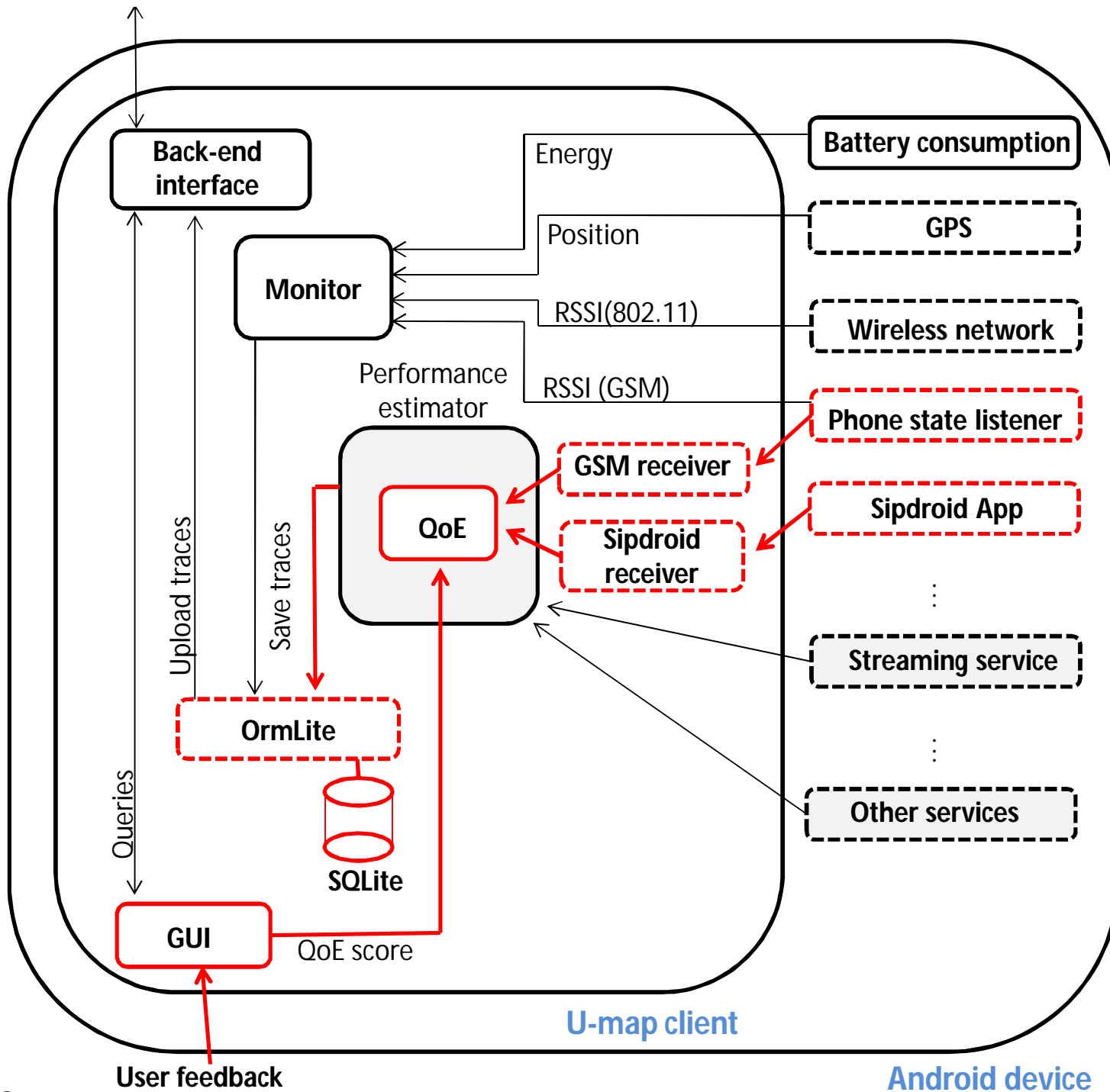
# U-map client



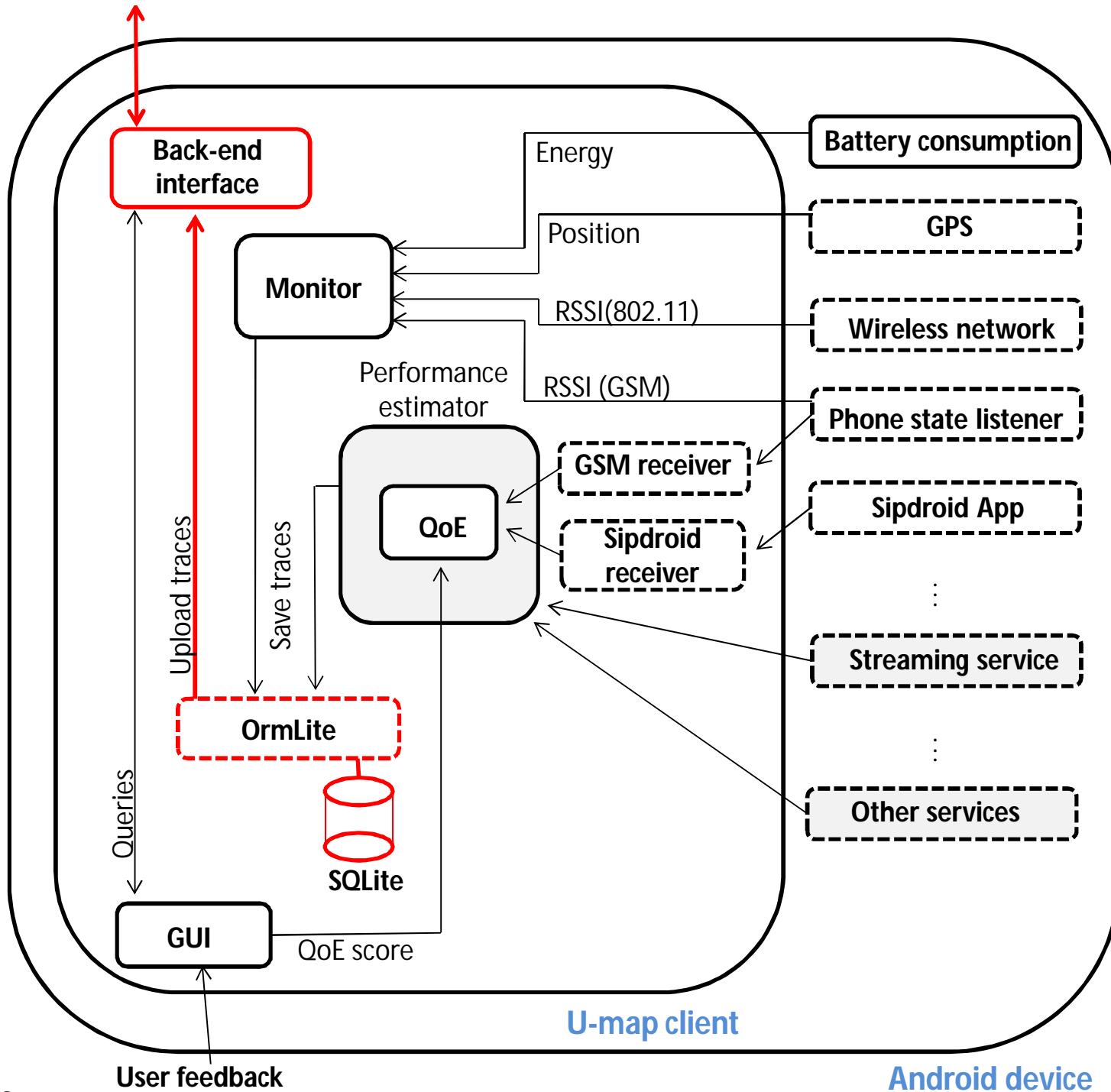
# U-map client



# U-map client

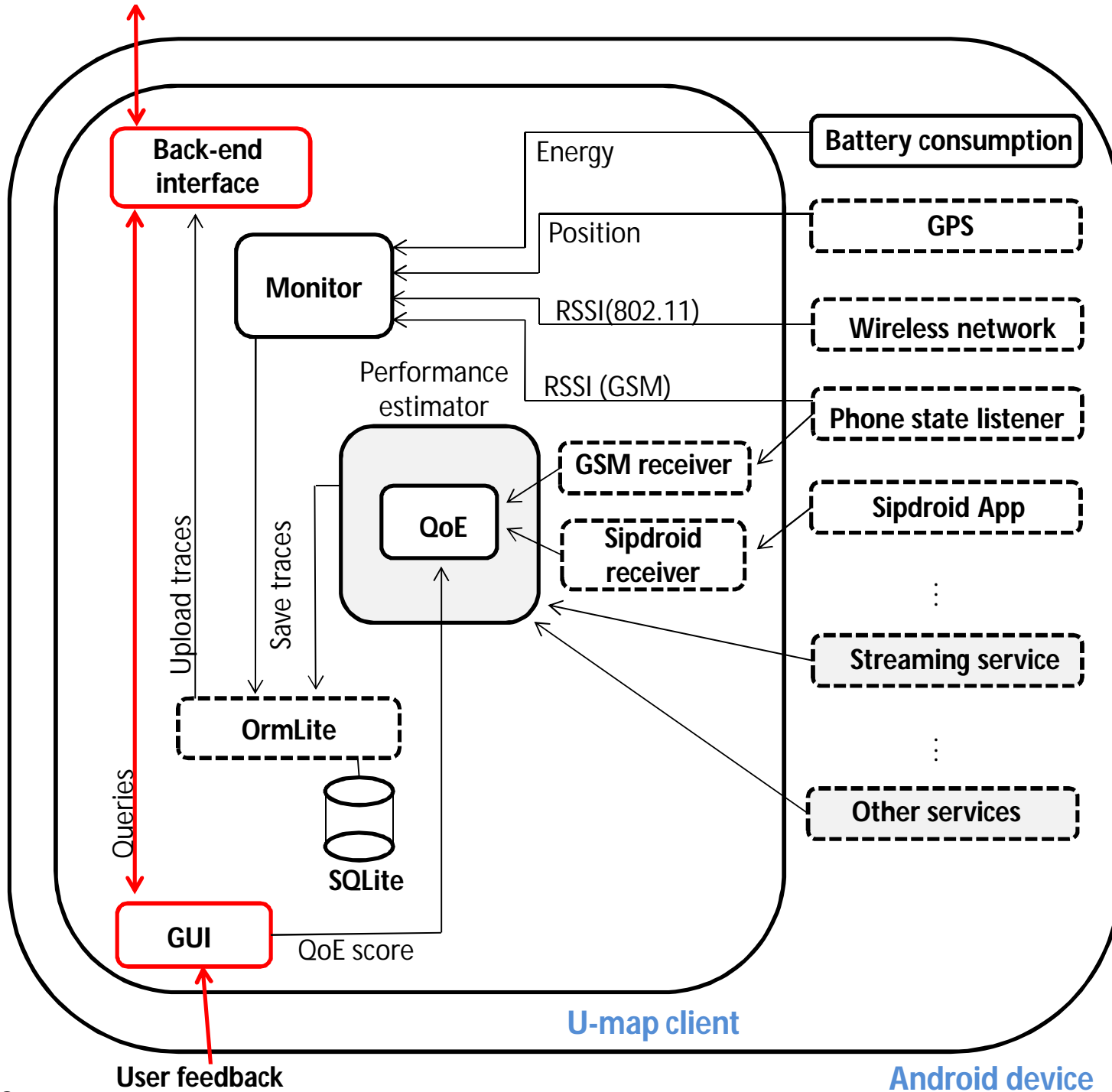


# U-map client

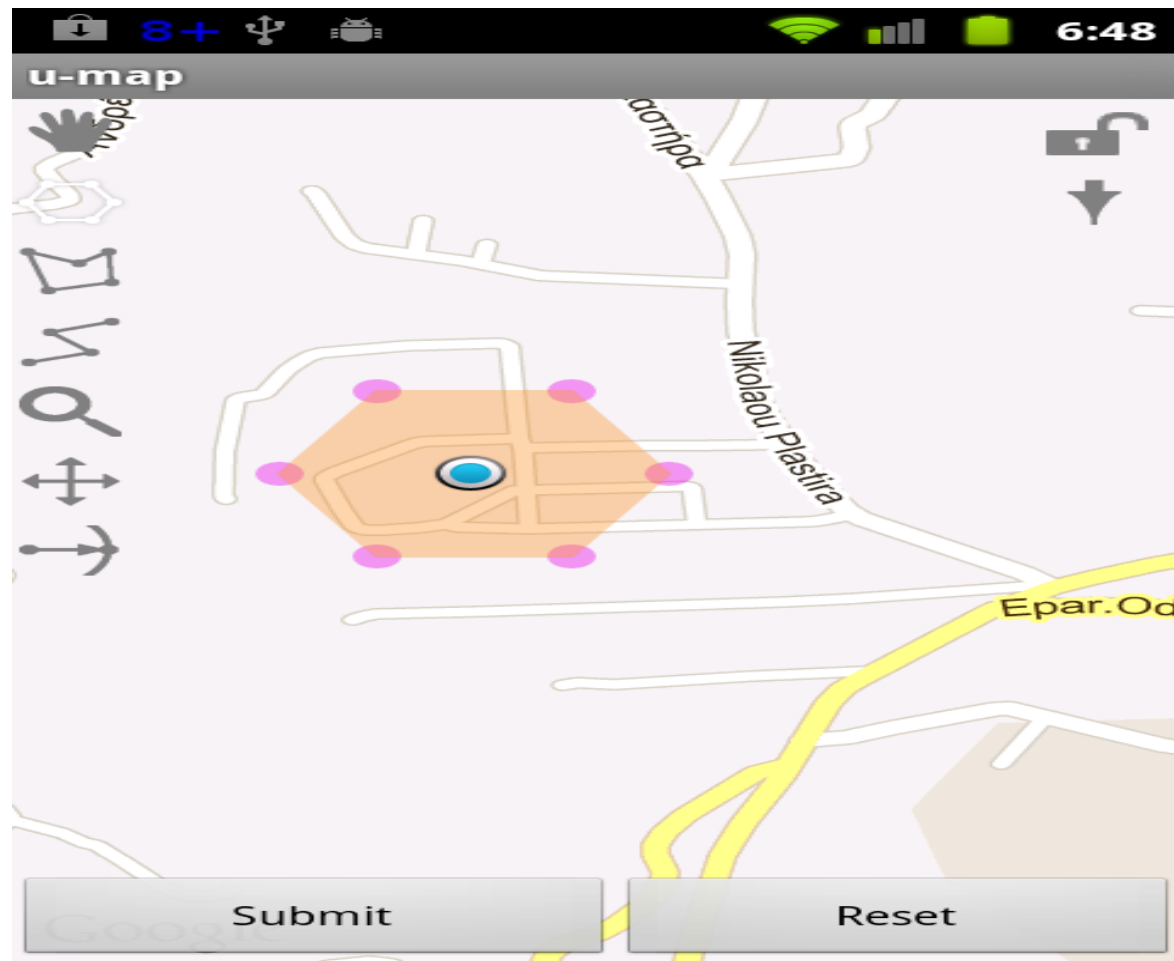




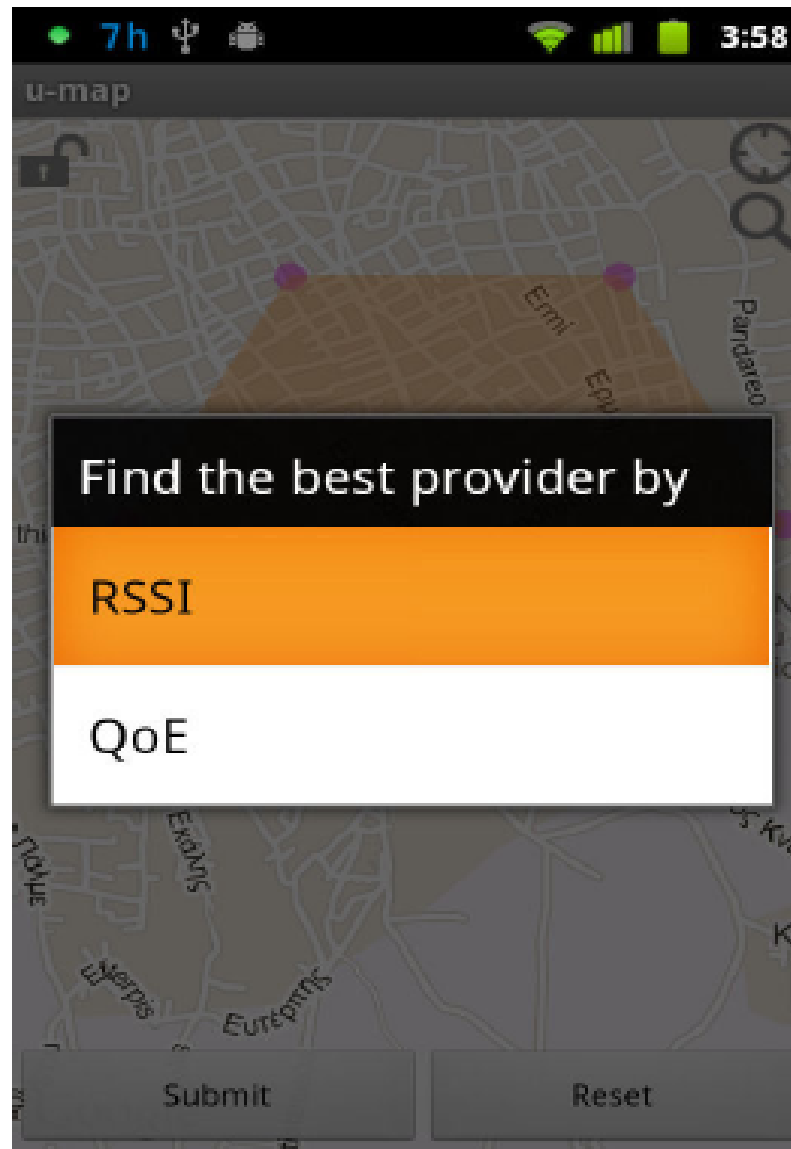
# U-map client



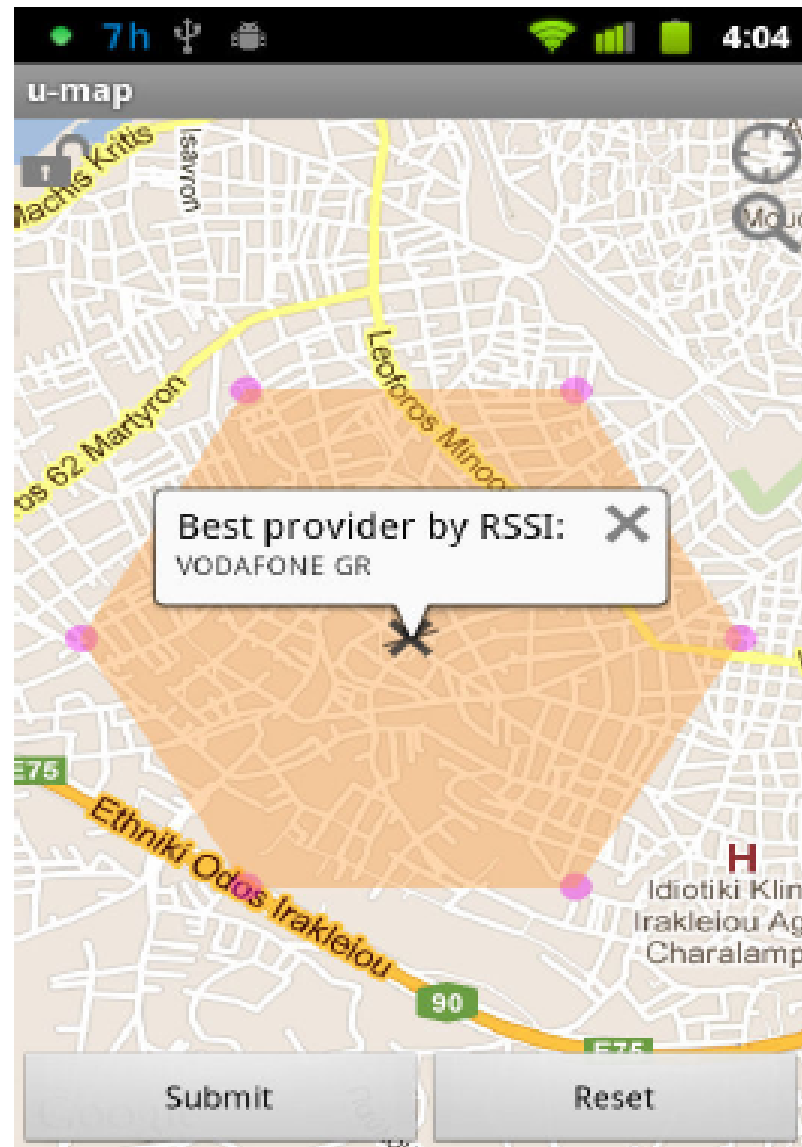
# U-map client GUI: Define area for query to discover the best provider



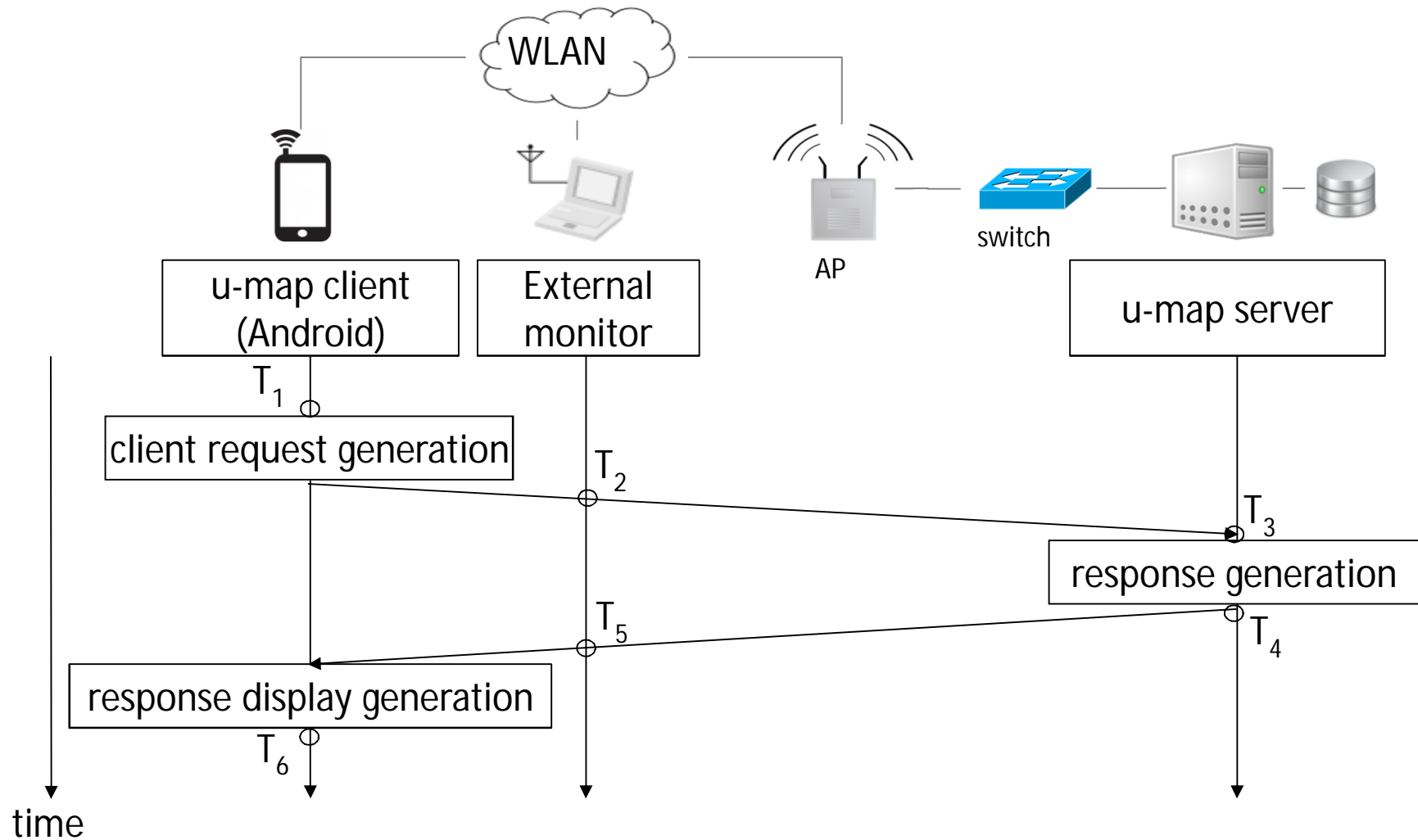
# U-map client GUI: Choose criterion

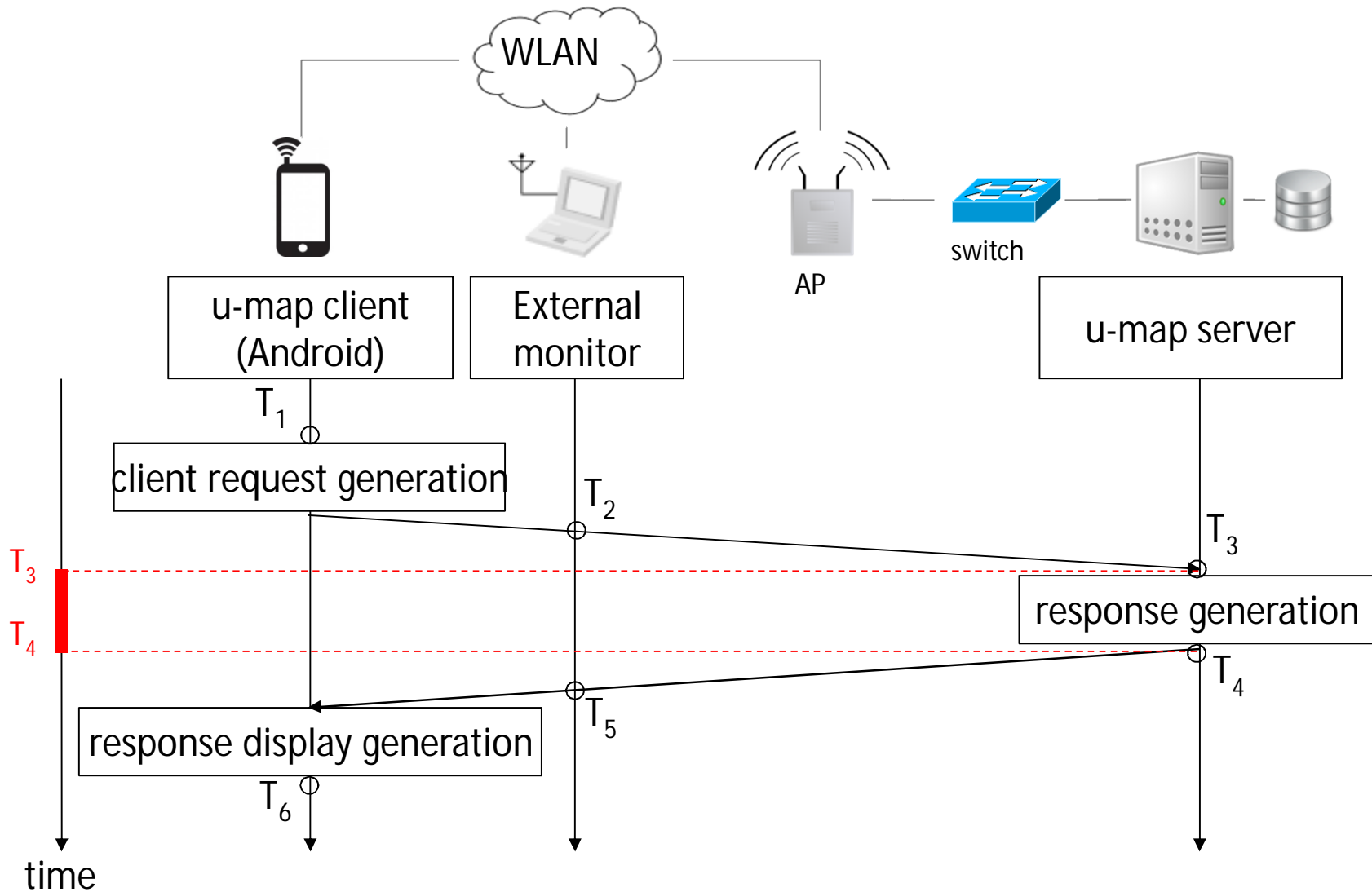


# U-map client GUI: Display result

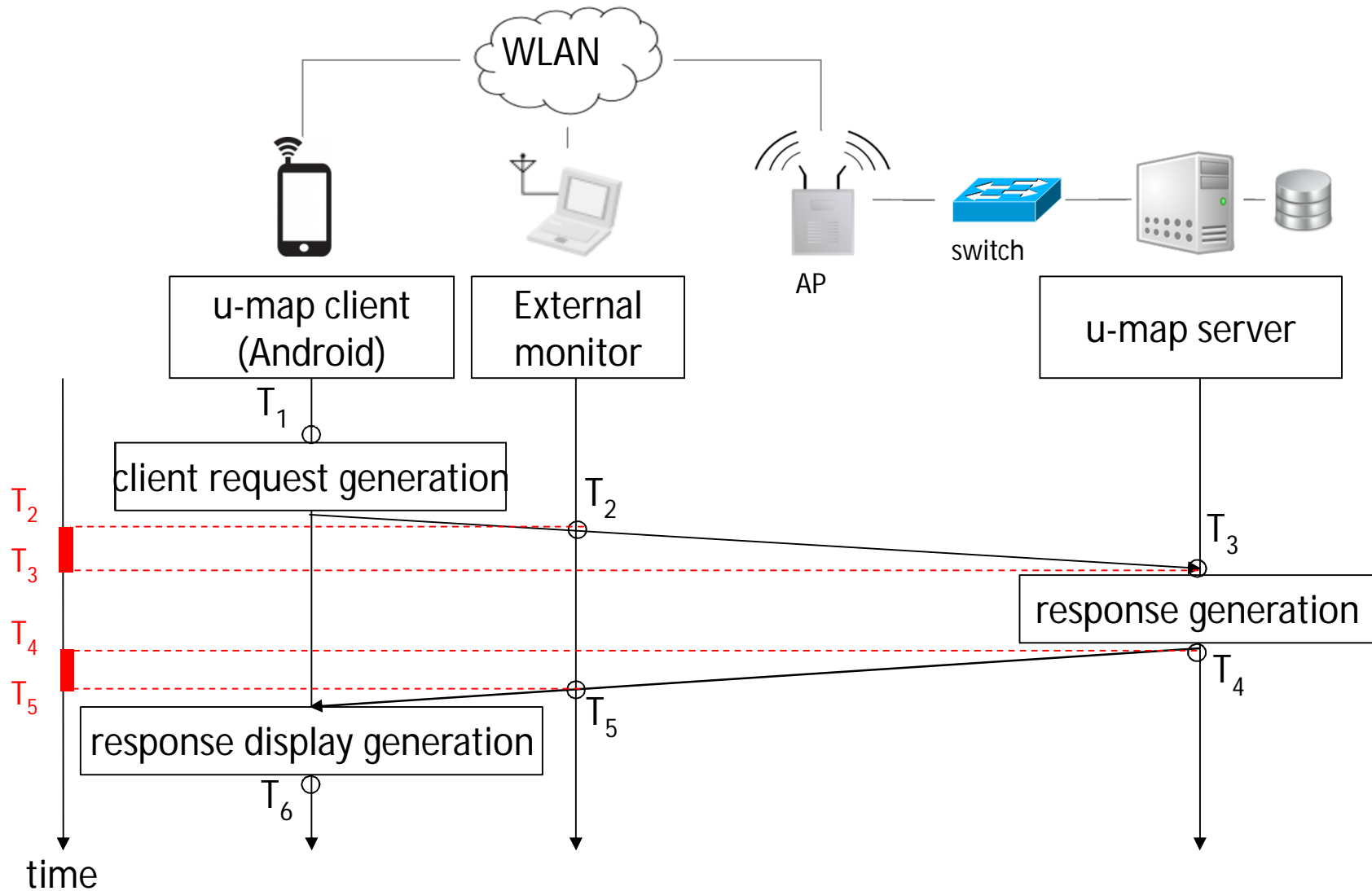


# U-map performance evaluation: Delays, scalability, power consumption

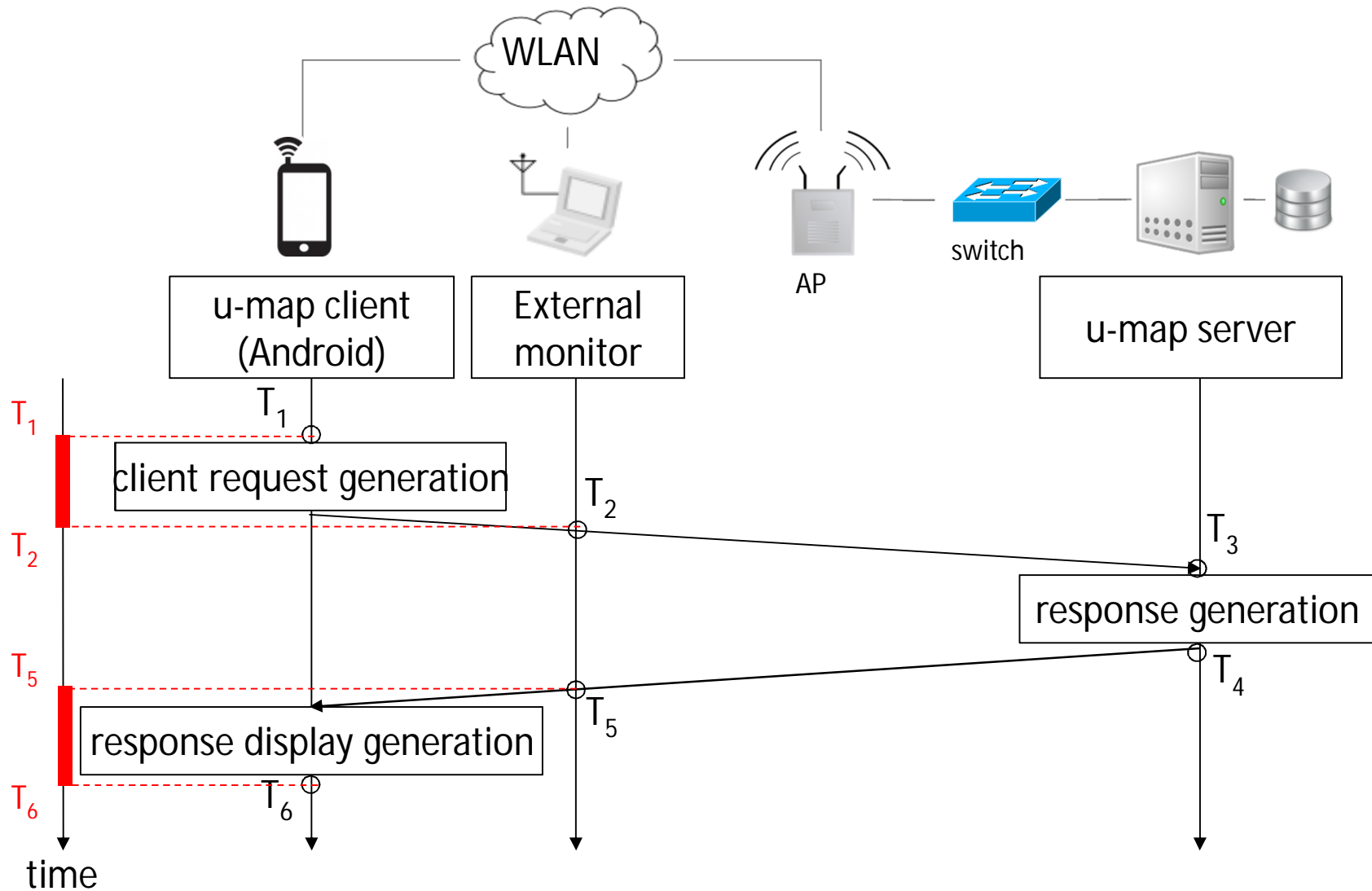




**Server delay:** Time for reception of request & transmission of response ( $T_4 - T_3$ )

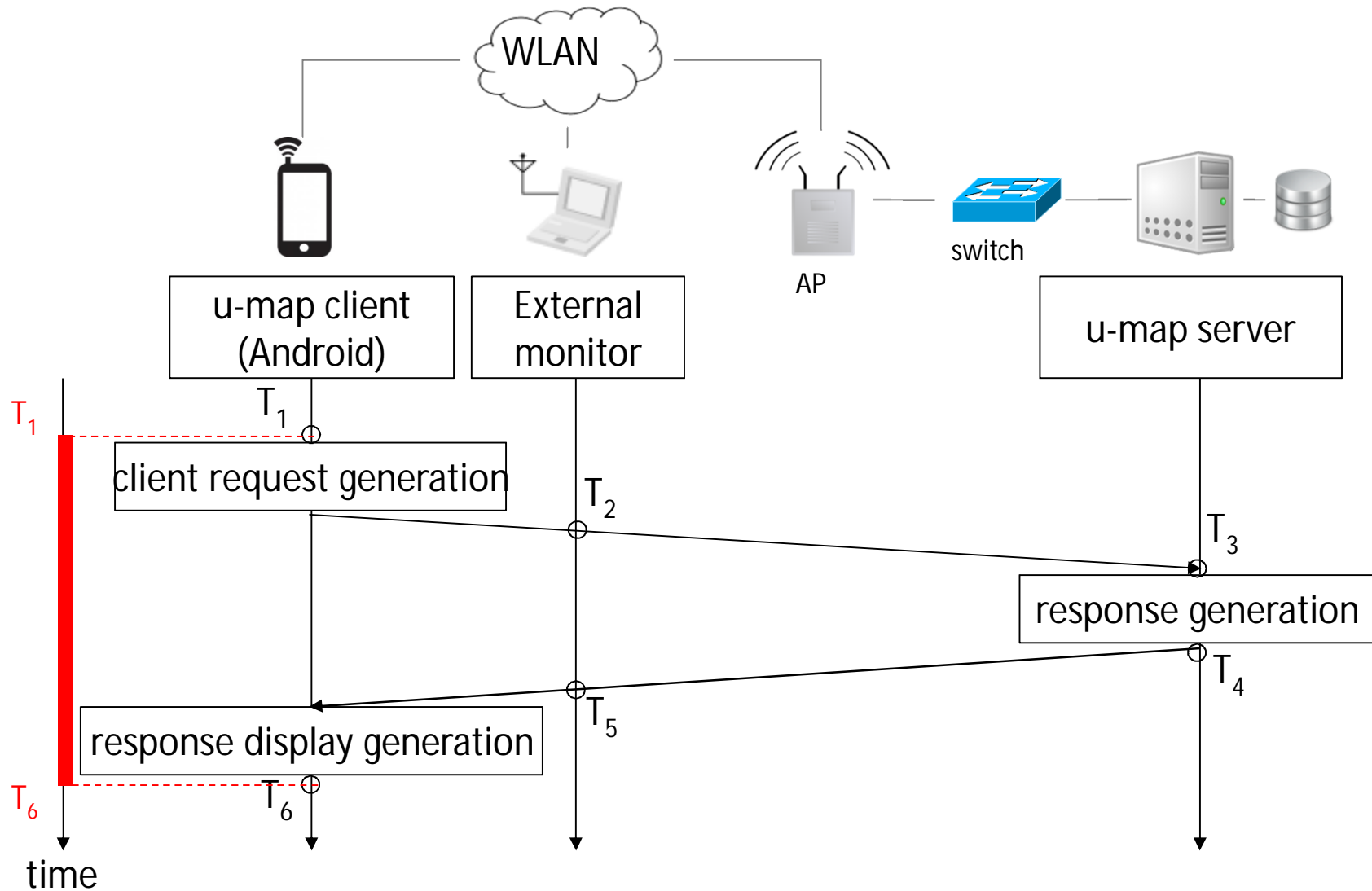


**Network delay:** Time for request to reach server & response to reach client  
 $(T_3 - T_2 + T_5 - T_4)$



**Android delay:** Time for request generation & display of response ( $T_2 - T_1 + T_6 - T_5$ )

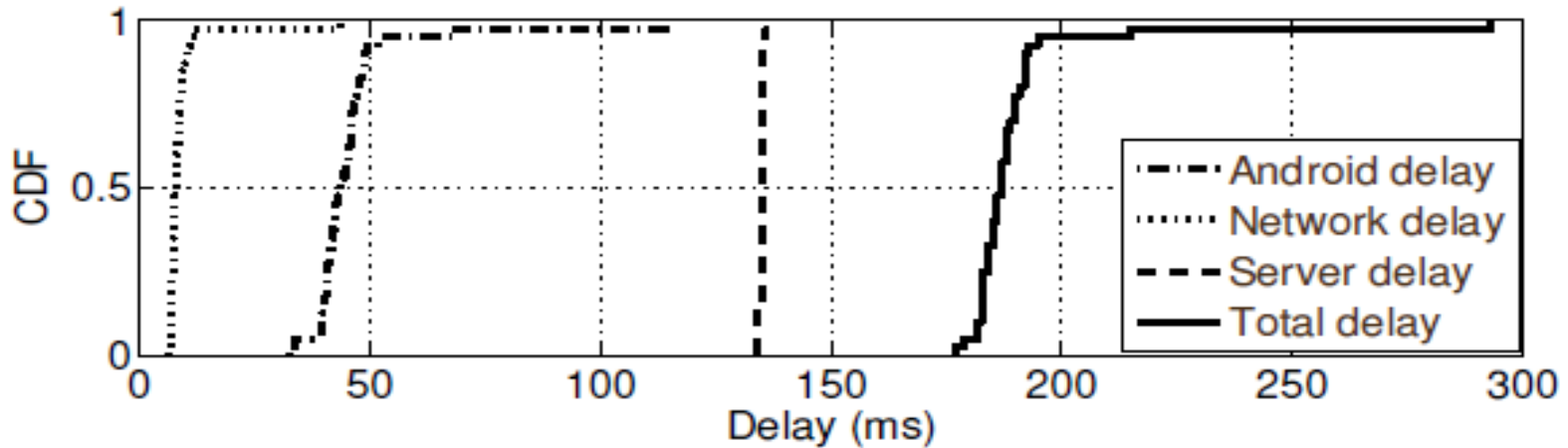




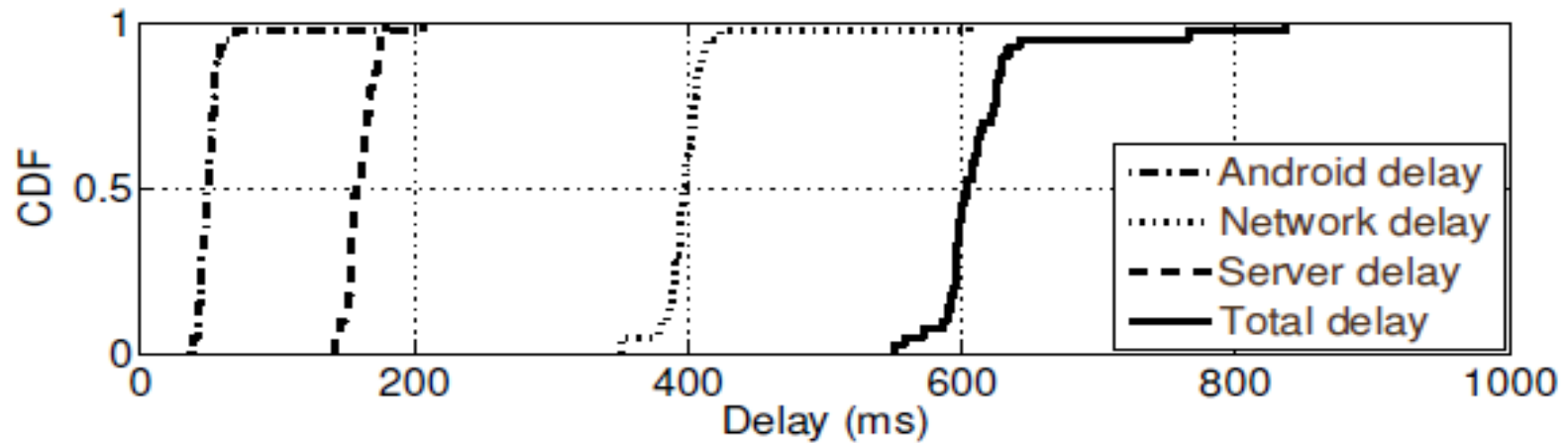
**Total Delay:** Total delay user experiences ( $T_6 - T_1$ )

# U-map performance: Delays

## Sending queries

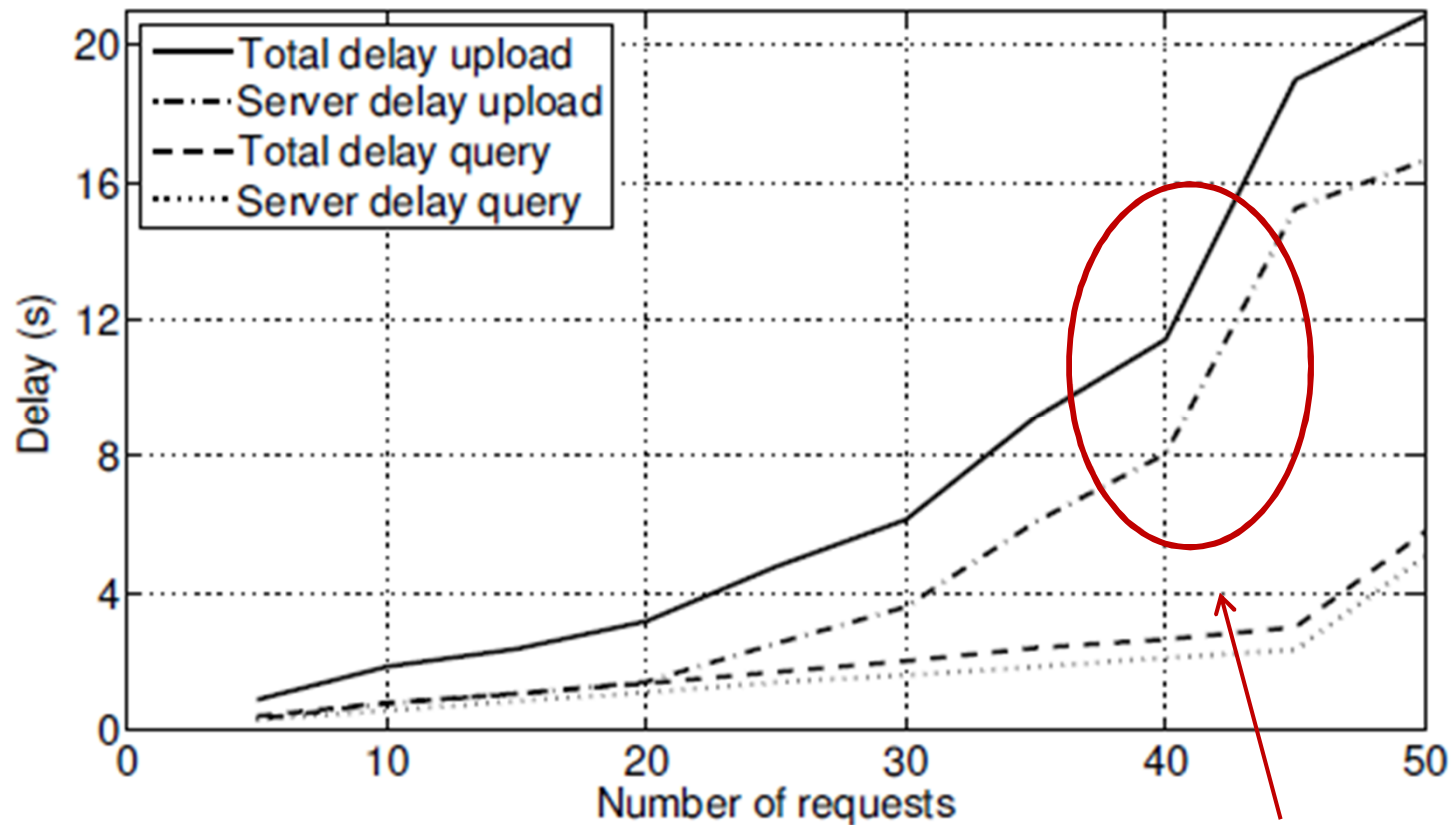


## Uploading traces



# U-map performance: Scalability

- Desktop PC emulating concurrent u-map clients



Prominent increase due to memory requirements

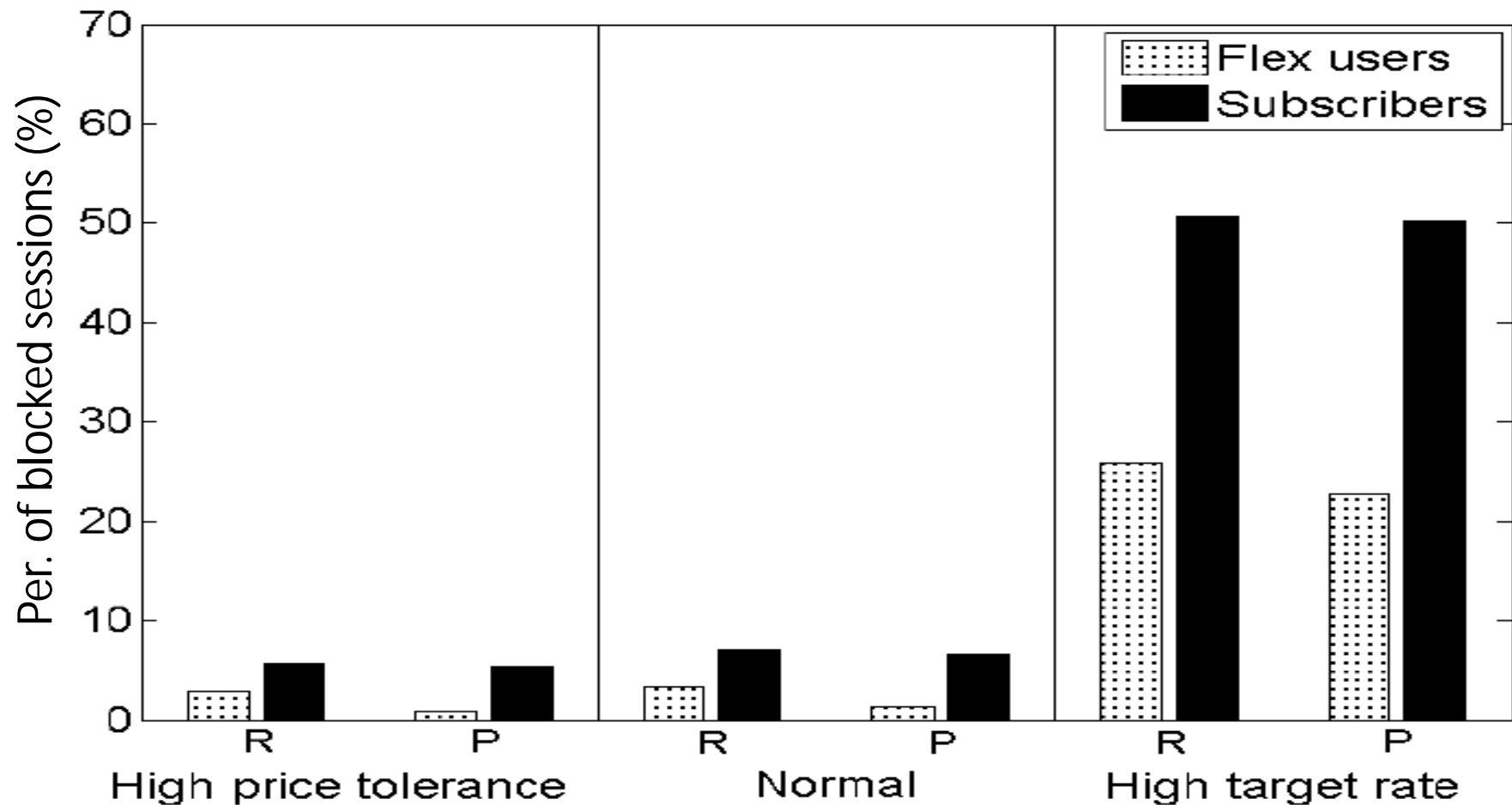
# U-map performance: Power consumption

Recorded with PowerTutor application

- IEEE802.11 wireless interface
- OLED display
- CPU

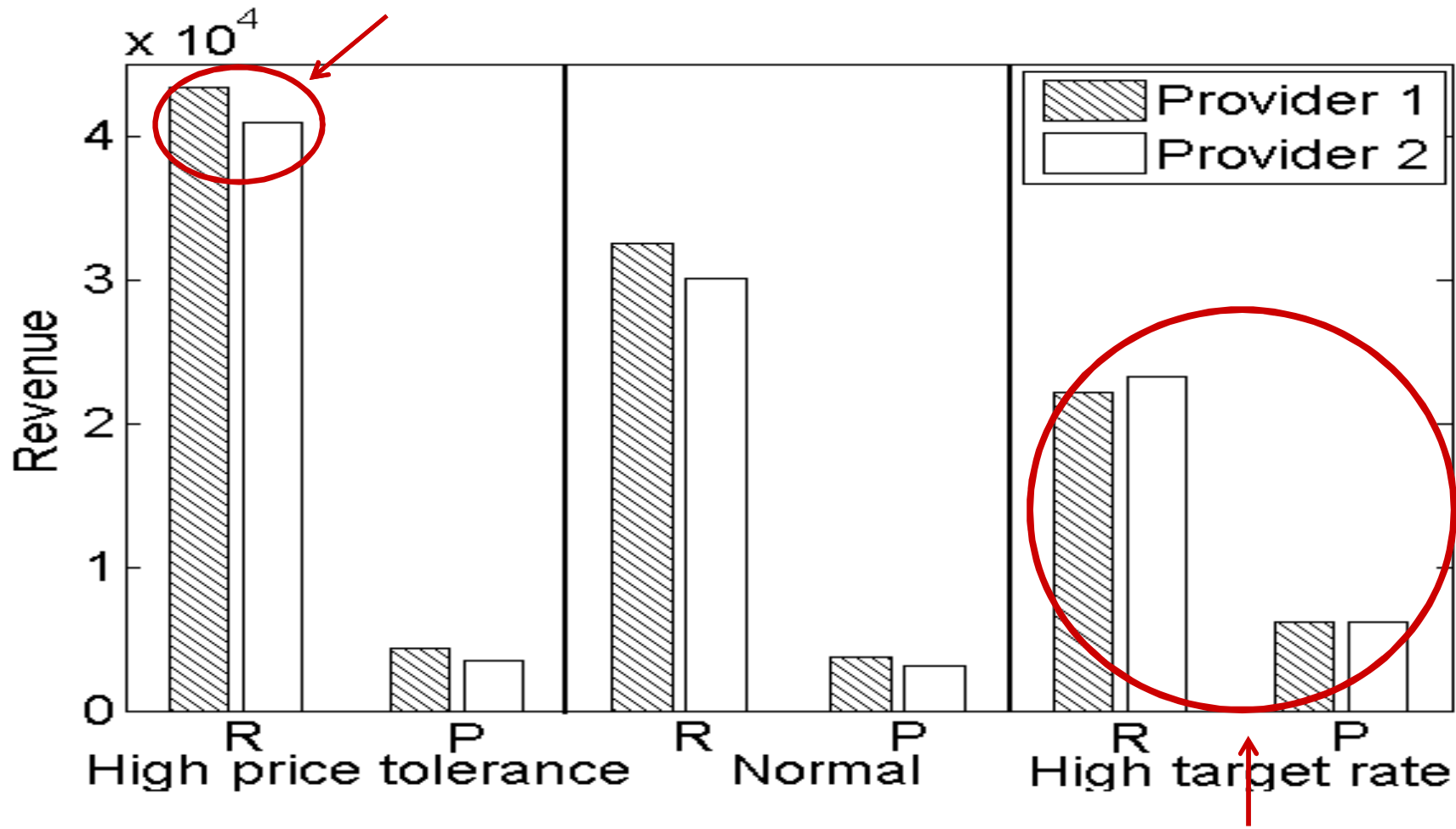
Power consumption under operations

- transmitting queries
  - OLED display prevails by 97% (401 mW)
- uploading traces
  - Wireless interface prevails by 97% (412 mW)



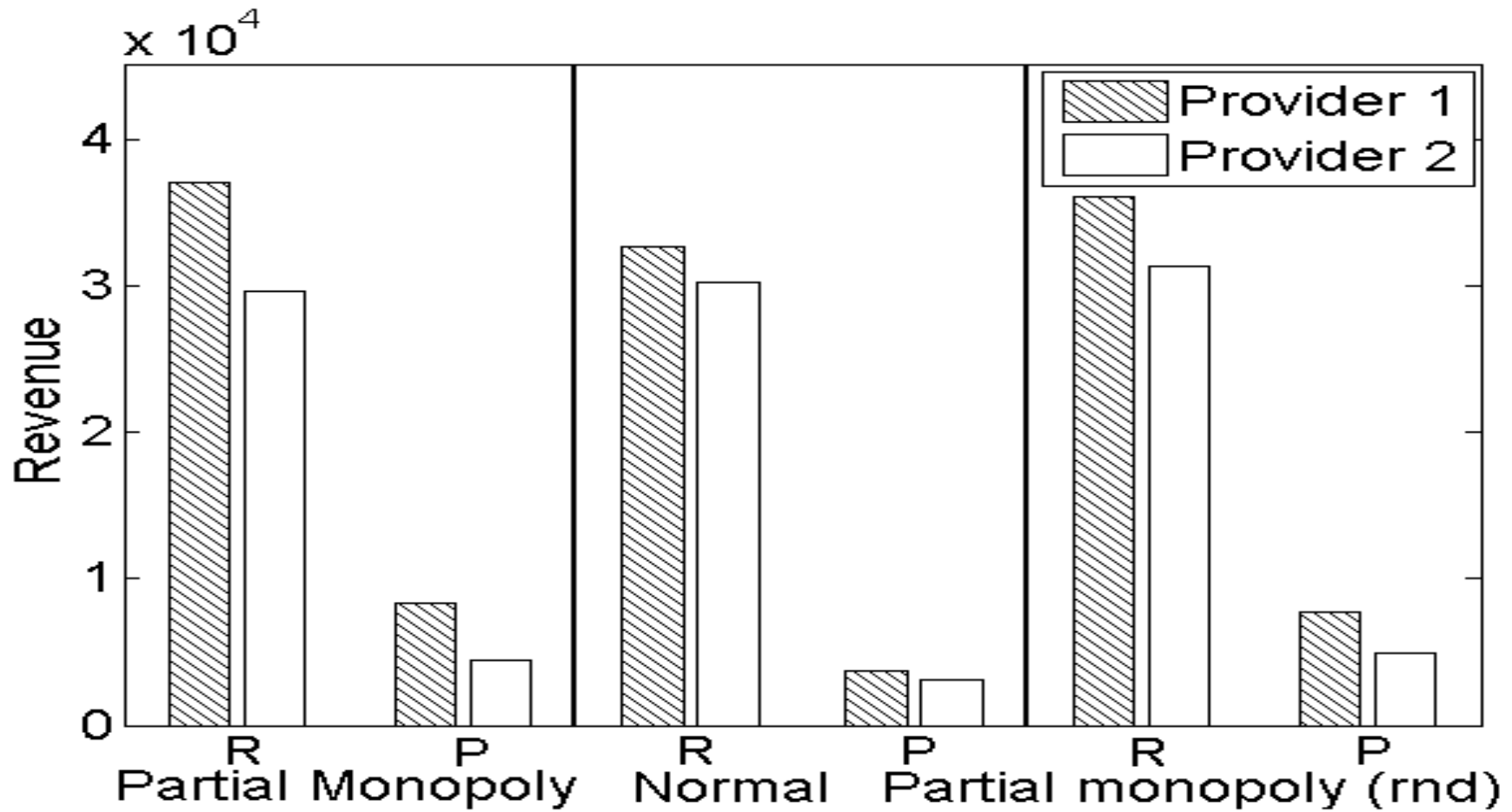
👉 **Flex users:** Almost half blocking probability compared to subscribers

**Rate preference: revenue increases**



**Rate preference: Revenue decreases**  
**Price preference: Revenue increases**

👉 Higher revenue in rate preference compared to price preference



Price preference: Revenue increases

Higher revenue in rate preference compared to price preference

# Conclusions

- Performance evaluation of u-map
  - Low **delays** and **power consumption**
  - Feasibility of u-map in real environment
- Modeling and simulation
  - U-map is **beneficial** to users
  - Flex service improves performance of users



# Ongoing and future work

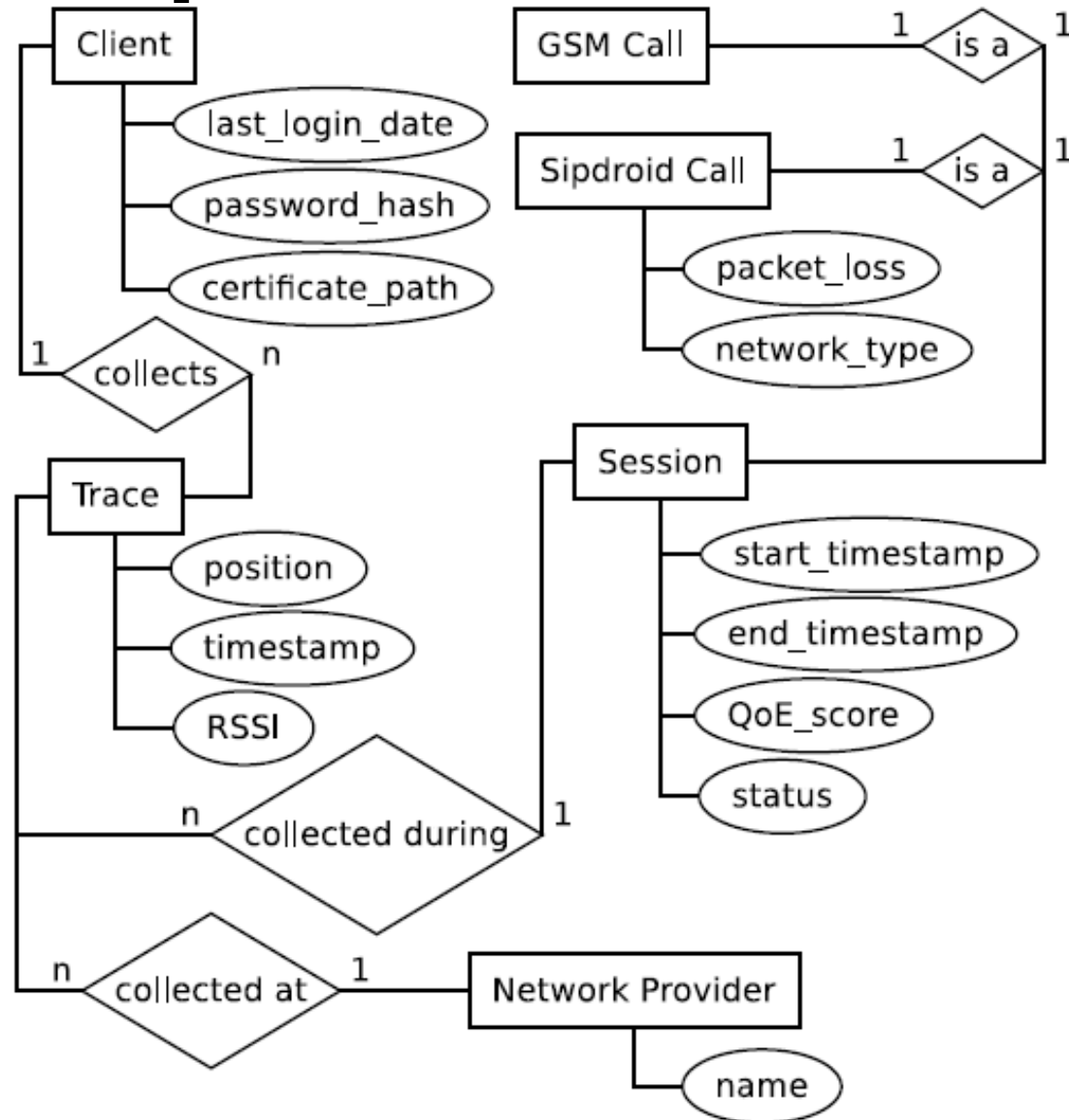
- Extend **modeling framework**
  - Various spatial distribution, mobility, and traffic demand patterns
  - More realistic modeling of the u-map
- Develop the **access control** mechanism
- Study the impact of **incentives** for users to contribute to the u-map
  - Altruism, reputation, payment, free services
- Extend the performance analysis of the u-map
  - Software-defined radio to emulate “**virtual providers**”
- Perform statistical analysis of historical u-map traces
  - Detect “**weak spots**” of providers coverage

Thank you for your attention !

More info:  
Relevant publications at  
<http://www.ics.forth.gr/mobile>

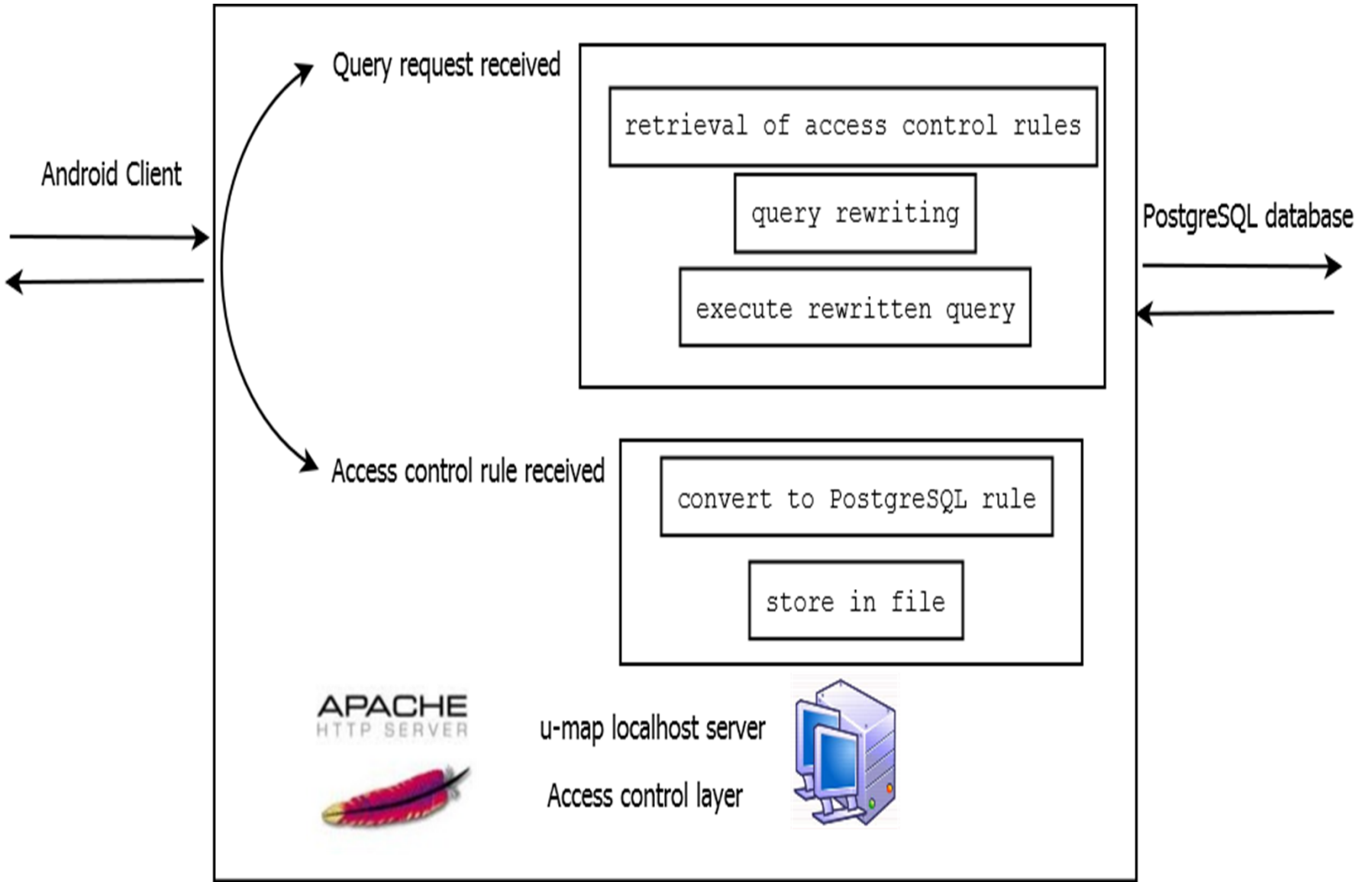
# Backup Slides

# U-map database ER Model



# U-map queries

- Customers
  - Best provider by RSSI value in specified area/time period
  - Best provider by QoE score of a service in specified area/time period
- Providers
  - Average QoE score of their customers in specified area/time period
  - Average RSSI value of their customers in specified area/time period
- Regulators
  - Average RSSI value of any provider in specified area/time period



```
SELECT AVG(traces)
FROM table.traces
WHERE area_contains(traces.position) AND
area > predetermined_size
```

```
SELECT AVG(traces)
FROM table.traces
WHERE area_contains(traces.position) AND
area > predetermined_size
AND TimePeriod(recent)
```

# Τέλος Ενότητας



Ευρωπαϊκή Ένωση  
Ευρωπαϊκό Κοινωνικό Ταμείο



Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

