UMOBILE ACM ICN 2017 Tutorial
Session: Contextualization Aspects Integration Into the Network Operation

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Rute Carvalho Sofia, Senception (rute.sofia@senception.com)
Paulo Mendes, Senception (paulo.mendes@senception.com)
Igor dos Santos (igor.santos@senception.com)
Session Overview

1. Contextualization in UMOBILE
   - The Context Plane

2. The Contextual Manager agent
   - Software architecture
   - Modules: capture, storage, inference
   - The A (affinity network), U (availability derived from usage), and I (similarity in preferences) weights

3. PerSense Mobile Light, a tool for network contextualization
   - Introduction to the tool (how to use it, results it provides)
   - Demo
1. Contextualization in UMOBILE
The Context Plane

- **Usage** – Time and space characterization of apps usage
- **User** – Time and space characterization of roaming behavior
- **Network** – Time and space characterization of a device’s neighborhood

**Plane is responsible for**

- Collecting
- Storing
- Resolving (e.g., providing metrics)

**Gives a measure of**

- Availability
- Betweenness

Context is
2. The UMOBILE Contextual Manager
The Context Plane
UMOBILE Contextual Manager

UMOBILE Gateway (1)
UMOBILE Service Manager (2)
UMOBILE End-user service (3)
UMOBILE Hotspot (4)

UMOBILE End-user service (3)
List of Apps (Oil, Now@, Route Planner)
NDN-Opp (background)
Contextual manager (background)
Kebapp (background)
NREP (background)

UMOBILE End-user Service

Contextual Manager

Router

NDN-Opp
Face
Opp Face
FIB

Kebapp
Face
Kebapp Fwd

NREP

Wi-Fi Direct
Bluetooth
LTE

External application
PerSense Mobile Light

External application
Oil!

External application
routePlanner

External application
Now@
Contextual Manager
High-Level Architecture

**UMOBILE APPS**

**Inference Module**
- Affinity network characterization
- Usage and Similarity characterization

**Capture Module**
- Affinity network data (e.g. peer list and peer interests)
- Visited network data (e.g. connectivity characterization)
- Resource Usage (apps, CPU, battery)

**Storage Module**

**Contextual Manager User interface** (handles requests and user config)

**Routing**
(1,2)

**NREP***
(3)

**Achieved**
**Under Implementation**
**Not implemented**
Contextual Manager
Capture Module: Visited Networks

- Visited networks
  - Individual roaming behavior
  - Data collected via regular Wi-Fi scans
  - Stores computed data for 1 week (1 table per day of the week)
  - Table entry is tuple: `<int AP Id, String HASHED SSID, String HASHED BSSID, int dayoftheWeek, int number_visits, double average_visitduration, int firstConnectedTimeStamp, int lastConnectedTimeStamp, boolean Connected, double lat, double lon>`

- Related Libraries: PerSense Mobile Light
Contextual Manager
Capture Module: Affinity Network

- **Affinity Network**
- Snapshot of the neighborhood availability over time and space
- Stores raw data for 1 week (1 table per day of the week)
  - Each entry in one day corresponds to one Peer, identified by HASHED BSSID
  - Table entry is tuple: `<int HASHED MAC, String UUID, int dayoftheweek, int array HourArray, double average_encounterduration, double lat, double long>`
- **Related Libraries: PerSense Mobile Light**
Contextual Manager
Capture Module: Resource Usage

- **Resource Usage**
- Stores resource consumption and app usage (per day and per hour)
- **Physical resource usage**
    - Energy: TypeofResource=energy
    - Storage: TypeofResource = Storage
    - CPU: TypeofResource = CPU
- **Category of application usage**
  - Entry: `<app_id, double TotalUsageDuration, double CPUConsumption, double connectivityConsumption, String CategoryPreferences>`

Contextual Manager Service

- Visited Networks
- Affinity network
- Resource usage
- Storage

- Wi-Fi
- Wi-Fi Direct
- Bluetooth

- Periodically (30 seconds)
- Periodically (60 minutes)

Apps, device resources
Contextual Manager
Storage Module

- **LOCAL SQL database**
- Table 1-7: visited networks (Monday to Sunday)
- Table 8-14: Affinity network (peer status, Monday to Sunday)
- Table 15-21: ResourceUsage (per hour, Monday to Sunday, multiple resources)
- Table 22-29 AppUsage (per hour, Monday to Sunday, multiple apps)
- Interface to external applications
  - Internal database synchronization feasible
- Contextual Manager Service manages requests and storing in database
- Periodic updates and refreshing
Contextual Manager
Inference Module, Indicators

**Affinity network characterization indicators**
- Peer list (bluetooth and Wi-Fi Direct) at instant t or over time window T.
- Interests associated to each peer.
- Battery status of each peer.
- Average, max, min connectivity duration over period T.
- Average, Max, min contact duration.
- Average node degree over time and space.
- Cluster distance.
- Visited networks’ characterization/ranking.

**Usage and similarity characterization Indicators**
- Preferred visited network and/or geo-location.
- Type (category) of preferred application (e.g. most used over time window T).
- Time spent per application category (e.g. per day).
- Similarity level computation towards (registered peers)
Contextual Manager
Inference Module, A and U Costs

- **U(i)**: internal usage weight of node i (measures availability of the node)
  - \( U(i) \): internal usage weight of node i
  - **A(i)**: affinity network level of node i (measures node betweenness)
    - **A(i)**: affinity network level of node i
  - **I(i,j)**: similarity for node preferences (measures similarity levels based on preferences)
    - **I(i,j)**: similarity for node preferences

- **U(i)**:
  - Battery status: 20%
  - Storage status: 80%
  - **U(i)**: Low (availability)

- **A(i)**:
  - Node I degree: 10
  - Average encounter duration: 1h
  - **A(i)**: high betweenness for node i

- **I(i,j)**:
  - Node i has as main preferences (out of 10 main preferences) Music, Art: [1,1,0,0,0,0,0,0,0,0]
  - Node j has as main preferences: Music, Literature: [1,0,1,0,0,0,0,0,0,0]
  - Node k has as main preferences Art and Literature: [0,1,1,0,0,0,0,0,0,0]
  - **I(I,j)=I(I,k)** - Node similarity level (computed based on eigenvalue distribution)
3. PerSense Mobile Light, a Tool for Network Contextualization
Non-Intrusive Wireless Technology
PerSense Mobile Light, what For?

- **Android App** developed in the context of the H2020 UMOBILE project
- **What it does**: mines wireless networks non-intrusively
  - Wi-Fi and Wi-Fi Direct; Bluetooth
  - Captures wireless foot printing aspects (distances, APs, visits type and duration and geo-location)
  - All data are stored LOCALLY and in accordance with European guidelines
  - Generates csv reports daily – researchers can get them via e-mail.
- **PML does not collect any personal data**
  - **Its Purpose**: industrial investigation - scientific studies and traces concerning roaming and interaction aspects
  - **Can be extended upon request, to capture parameters relevant to interested parties**
- **Where it is being (further) applied**:
  - PhD students, smart cities data extraction
  - UMOBILE Lab (soon, to be open to the external community)
- **Questions? Info at senception dot com**
PerSense Mobile Light

How to Run?

• Google App store (Android only)

• Start the app
  Runs in background
  Stores the reports after 1 day in a folder named PerSense_mobile_light

• How to extract results
  • Open the app and send reports via e-mail OR
  • Go to the internal memory and get the csv files (three different reports per day)

• How to visualize results?
  • Use a mining tool (e.g. Orange, RapidMiner)
  • Soon: UMOBILE Portal (February 2018)
PerSense Mobile Light
Interaction Reports

Three different reports generated daily

- **Roaming Diary (APs crossed)**
  - *Id.* Sequential identifier of the AP waypoint crossed;
  - *Bssid of the AP; Ssid of the AP*
  - *Dayoftheweek.* Integer corresponding to the day of the week, starting by Sunday as 1, and ending with Saturday (7)
  - *Attractiveness.* Boolean (0 not connected; 1 connected)
  - *DateTime.* day and time when the device entered the range of the AP.
  - *Latitude, Longitude.* GPS coordinates for the device.

- **Visited Networks’ report, list of access points the device connected to.**
  - *Id.* Sequential identifier of the AP waypoint crossed;
  - *Bssid of the AP; Ssid of the AP*
  - *Timeon.* Timestamp for the start of the connection (MAC Layer)
  - *Timeout.* Timestamp for the end of the connection
  - *Dayoftheweek.* Integer corresponding to the day of the week, starting by Sunday as 1, and ending with Saturday (7). Hour corresponds to the 24-hour timeslot of the day.

- **Affinity network report** provides a list of neighbors over time (affinity network).
  - *(id); identifier of the device (uuid);*
  - *MAC address (MAC);*
  - *DateTime.* date and time when the peer was last encountered
  - *Lat, Long.* GPS coordinates for the device.
PerSense Mobile Light

Study I: Social Interaction Analysis in Children*

- 80 students, ages 11-16
- 8 different classes
- 8-10 teachers
- 1 month data collection

Data collected, 1 day (05.05.2017)
connected (1) vs crossed access points (0 – blue)

Data collected, 1 day (05.05.2017)
distribution of visited APs over time

Study on clustering and time correlation of roaming habits/mobility patterns in children
Mauro Bianchi (mauro.bianchi@ulusofona.pt, COPELABS/CTIP), Anna Pegna (anna_pegna@iscte.pt, ISCTE-IUL),
Rute Sofia (rute.sofia@ulusofona.pt, COPELABS/Senception), Igor dos Santos (igor.santos@senception.com, Senception)
Ana Loureiro (ana.loureiro@ulusofona.pt, COPELABS/CTIP), Joana Santos (jsantos1103@gmail.com, EPCV/ULHT)
Ricardo Rodrigues (ricardo.rodrigues@iscte.pt, CIS-IUL)
Main Results

- Results show that it is feasible to rely on network mining to extract concrete daily routine habits, e.g.,

- **Time-based characterization aspects**
  - Duration of a daily routine has in average 15 hours (instead of the common 8 hours routine used in network modeling)
  - There are three different higher connectivity periods during one day, each with a duration of 2-3 hours (usually tending to early morning; lunch time; late afternoon)
  - During a week, there is a one-day period of more intense connectivity, and a one-day period (usually Sunday) of lower connectivity usage

- **Spatial characterization aspects**
  - In the traces obtained, the paths traversed held thousands of AP per day, at a close distance (0.09m-100m)
  - Maximum traversed distance in 1 day: ~ 10 km
  - Average distance: hundreds of meters

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