Fast Spectral Assessment for Handover Decisions in 5G Networks

Kostas Chounos, Stratos Keranidis, Apostolos Apostolaras and Thanasis Korakis

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NITLAB
NETWORK IMPLEMENTATION TESTBED LABORATORY

UNIVERSITY OF THESSALY

Outline

- ✓ Motivation / Contributions
- ✓ Proposed System
- ✓ System Verification
- ✓ Experimental Evaluation
- ✓ Conclusions

Motivation

- **Q1: What is the capacity crunch?**
  - The congestion of cellular networks, which occurred from the sharply increased demand for wireless services.
- **Q2: Are there any approaches for overcoming this problem?**
  - Intense research effort has been conducted in cellular systems for the alleviation of the capacity crunch problem.
  - The vast majority of the approaches steer the offloaded data to Wireless Local Area Networks (WLANs).
- **Q3: Why performance-aware Mobile Data Offloading?**
  - Performance of IEEE 802.11 protocol is degraded due to extensive ISM spectrum sharing.
  - Lack of unified mechanisms for characterizing the impact of interference and steer the offloaded data into controlled environments.

Contributions

- ✓ **In this work, a UE-driven mechanism for fast handover decision and WLAN selection is proposed in the context of 5G networks.**

- ✓ Main features:
  - ✓ Spectrum-aware roaming and association decisions.
  - ✓ A ready-to-be deployed Solution.
  - ✓ Light-weight with minimum signaling required.
  - ✓ Low computational and processing costs added.

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Proposed System

- The proposed framework could be distinctly separated into the three following phases:
  - **Collecting Spectral Measurements:** During this phase, the wireless interface collects raw energy spectral samples.
  - **Inferring Spectrum Utilization:** At this point and based on the collected measurements, the developed algorithm exports the spectrum utilization for the channel(s) requested.
  - **Roaming Selection:** Finally, after spectrum analysis and evaluation, UE selects the preferred AP based on the performance predictions.

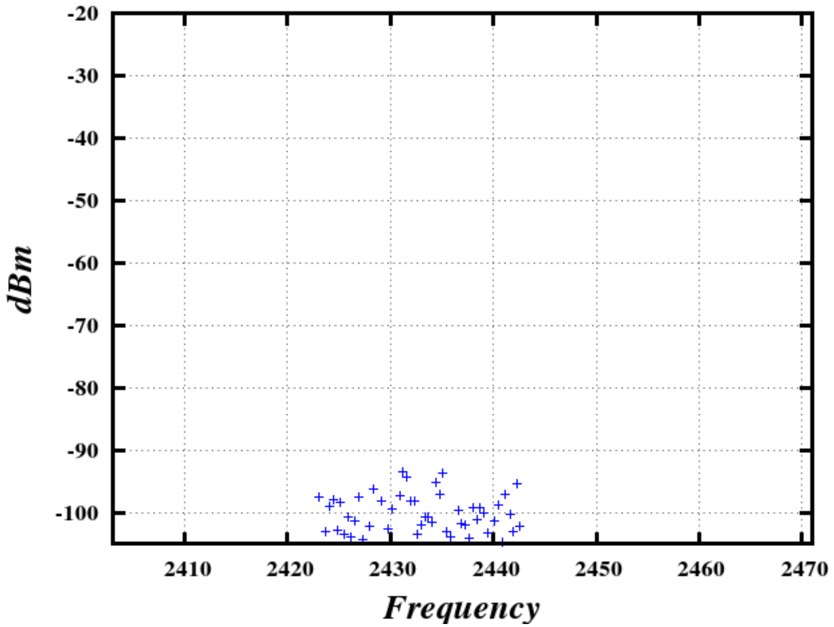
Collecting Spectral Measurements

- Take advantage of the available spectral measurements could be exported from commercial Qualcomm Chipsets.

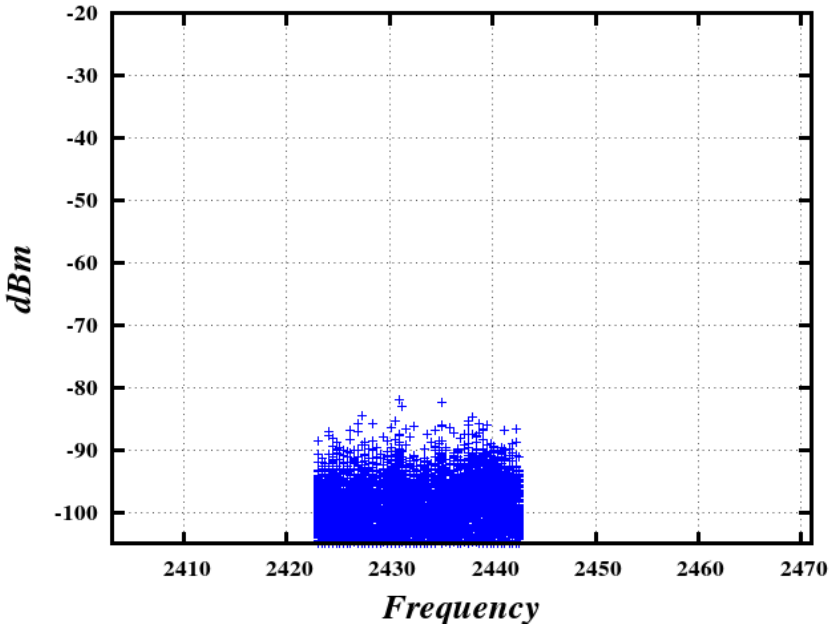
- Wireless hardware specifications:
  - Available FFT sizes **64 – 256** bins (**SC**) responds to 20 - 80MHz channel bandwidths.
  - All channels ($\mathbf{F_c}$) from both **2.4GHz** and **5GHz** ISM bands are available for scan.
  - Channel switching time ~1ms.

- Typical spectral scans contain
  - Several center frequencies (channels) for scan.
  - Multiple spectral samples for each frequency.

Collecting Spectral Measurements



1 spectral set (**S**) for channel 5



250 (**NS**) spectral set for channel 5

- ✓ In the proposed framework we:
  - ✓ Use 64 bin FFT.
  - ✓ Obtain 250 spectral samples for every channel scanned.

Inferring Spectrum Utilization

- ✓ A user-space algorithm converts the spectral measurements to **Duty Cycle** (**DC**) at each frequency (**F_c**).
- ✓ The DC metric represents the percentage of time in which the power exceeds a predefined power threshold.

$$\mathcal{P}(\mathcal{S},\mathcal{F}_c) = \sum_{i}^{\mathcal{SC}} \mathcal{P}(i,\mathcal{S},\mathcal{F}_c)$$

$$on(\mathcal{P}(\mathcal{S},\mathcal{F}_c),\mathcal{P}_{\mathcal{T}H}) = \begin{cases} 1 & \text{when } \mathcal{P}(\mathcal{S},\mathcal{F}_c) \geq \mathcal{P}_{\mathcal{TH}} \\ 0 & \text{otherwise.} \end{cases}$$

$$\mathcal{DC}(\mathcal{F}_c) = \frac{1}{\mathcal{N_S}} \sum_{S=1}^{\mathcal{N_S}} on(\mathcal{P}(\mathcal{S},\mathcal{F}_c),\mathcal{P}_{\mathcal{T}H})$$

Roaming Selection

In our approach, the WLAN selection decision is based jointly on perceived spectrum occupancy (**DC**) and **RSSI** metrics.

- ✓ **UE** side:
  - ✓ Through beacon frames, UE retrieves the RSSI values for each AP candidate available.
  - ✓ Refreshes its local spectral conditions by periodically performing **Phases 1** and **2**.
- ✓ **AP** side:
  - ✓ Respectively, **Phases 1** and **2** are activated for each AP candidate and only in its operating frequency ($\mathbf{F_c}$).
  - ✓ Passes its frequency spectral utilization to the UE.

Roaming Selection

- In this context, the least normalized capacity (Mbps) between the UE and each AP candidate can be exported from:

$$C_{ua} = (1 - \mathcal{DC}_{\max}) * \mathcal{C}_{Th}$$

where:

- ***DC_{max}*** is the worst case of occupied spectrum either at AP's or UE's side as exported from **Phases 1** and **2**.
- ***C_{Th}*** is the theoretical data rate could be achieved from the predicted ***MCS_{ua}***.

- In this way, UE selects the AP candidate which maximizes the ***C_{ua}***.

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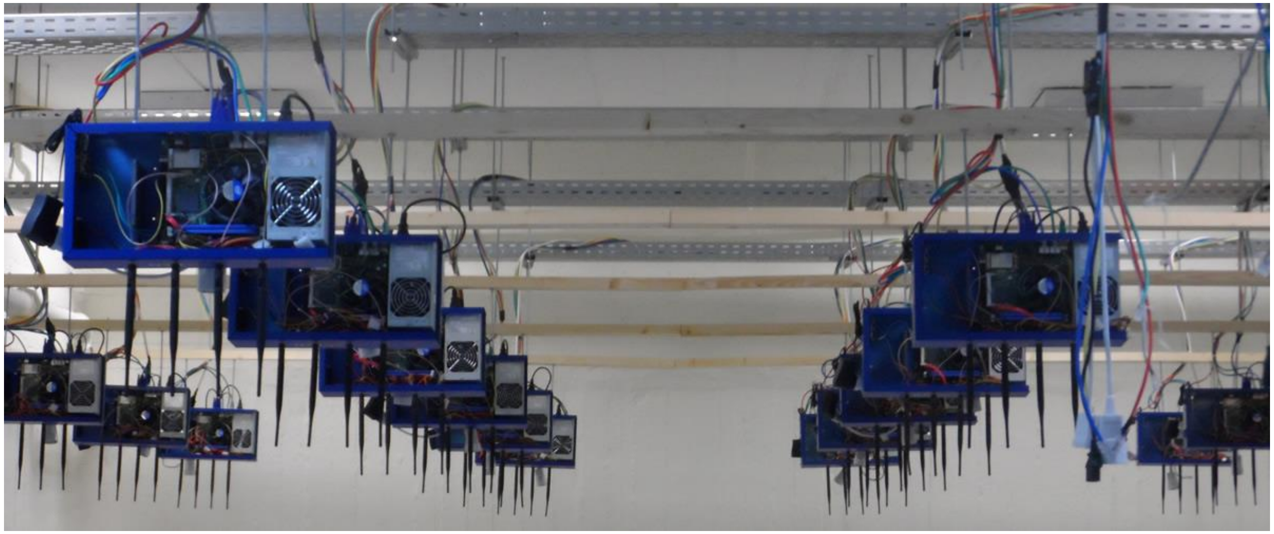
Experimental Infrastructure

- ✓ All the experiments were conducted in NITOS wireless testbeds
  - ✓ 24/7 remote access on the research community.
  - ✓ Large range of wireless hardware is available. (Wi-Fi, USRPs, LTE, WiMAX).
  - ✓ Varying interference environments (Both indoor and Outdoor Testbeds).



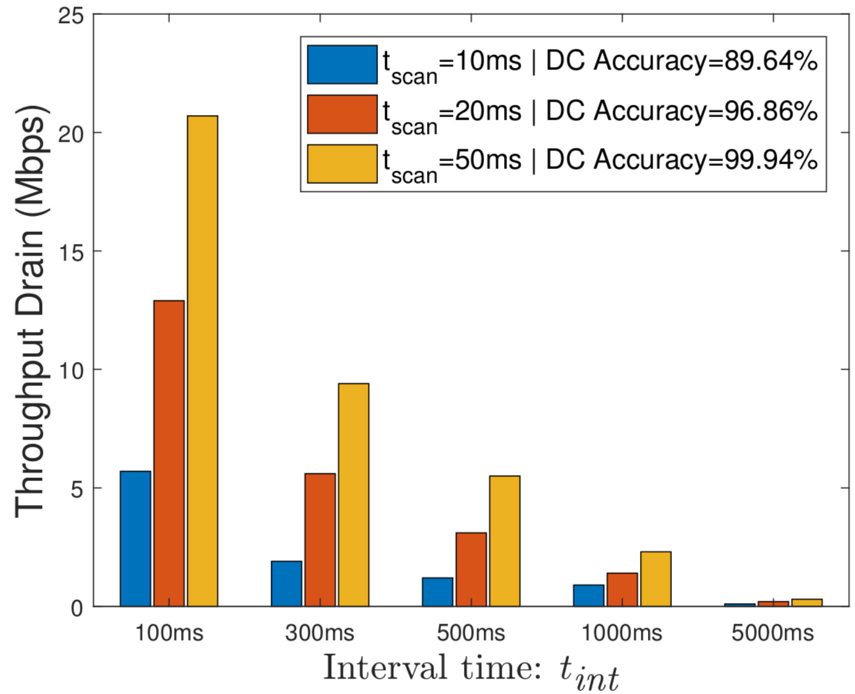
System Verification

- **Experimental Scope**
  - Observe how accurate is the spectral evaluation mechanism.
  - Measure the overhead added from the proposed framework.

- **Experimental Setup**
  - 1 USRP B210 for emulating a microwave oven's transmission
    - Operating Channel: 5.
    - Operating Bandwidth: 20MHz.
    - Channel Utilization: 50%.
  - 1 IEEE 802.11 link for measuring the performance drains.
    - Operating Channel: 11.
    - Operating Bandwidth: 20MHz.
    - Traffic: 100Mbps of UDP unidirectional traffic from AP -> STA.

- **Examined Parameters**
  - t_{int} (how often the proposed framework is triggered).
  - t_{scan} ("on channel" time spent for scanning a particular frequency).

System Verification



Observations:

- ✓ More frequent (low $\boldsymbol{t_{int}}$ values) executions of the proposed framework occur larger performance drains (Mbps).
- ✓ Larger performance decays are appeared at higher $\boldsymbol{t_{scan}}$ values.
- ✓ Larger detection accuracy arises also at higher $\boldsymbol{t_{scan}}$ values.

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Experimental Evaluation

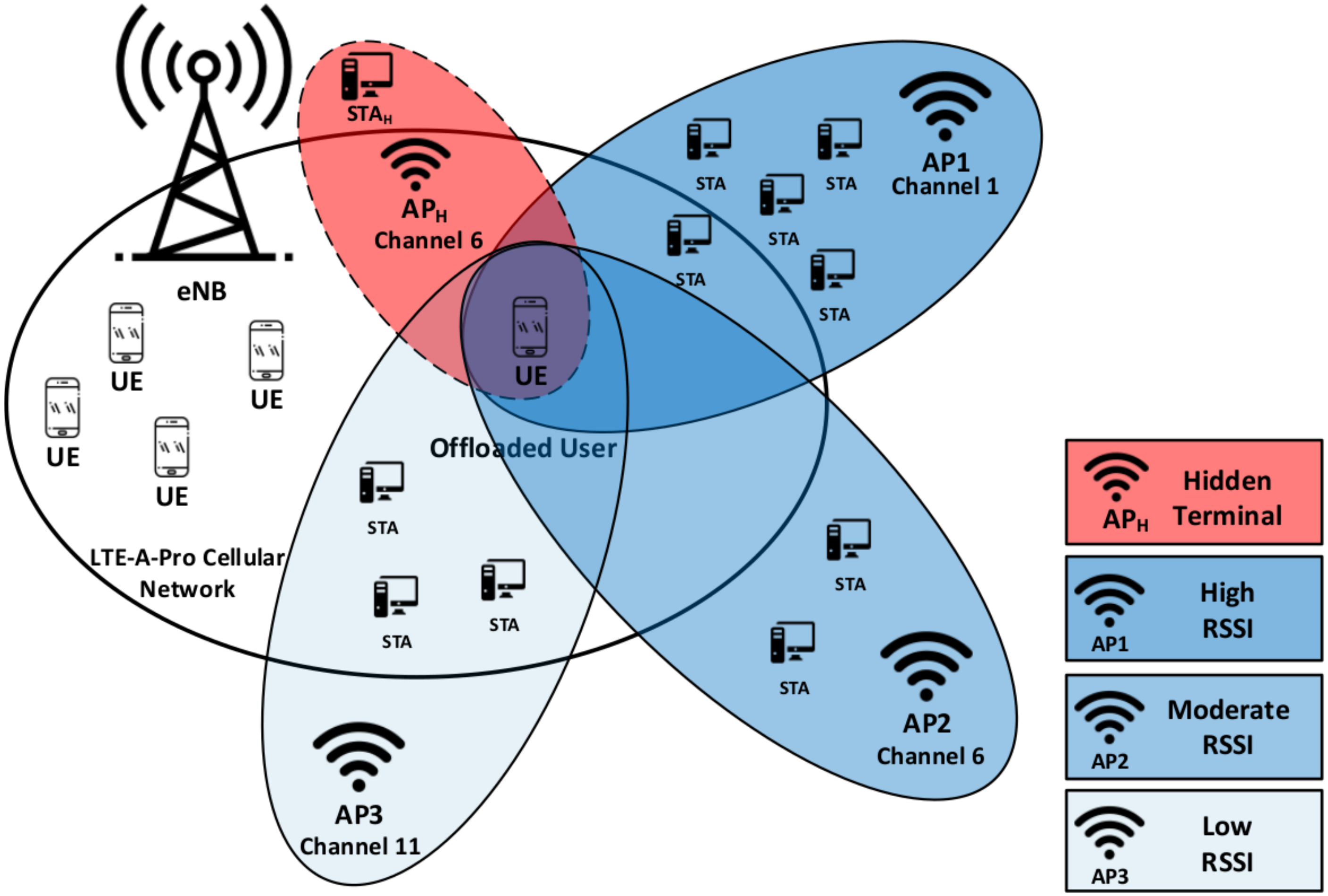
A mobile user (UE) intends to leave the cellular network and has it's traffic demand served through the available Wi-Fi AP candidates. We thoroughly examine how the throughput performance (Mbps) of a UE could vary depending on different AP association decision schemes.

- **Experimental Scope**
  - Observe how accurately each link's capacity is predicted.
  - Highlight that the spectral conditions may be completely different at UE and AP side.

- **Experimental Setup**
  - 3 Available AP candidates for serving the offloaded traffic.
    - High SNR (-36dBm) Operating Channel: 1, Associated Stations: 5.
    - Moderate SNR (-67dBm) Operating Channel: 6, Associated Stations: 2.
    - Low SNR (-75dBm) Operating Channel: 11, Associated Stations: 3.
  - 1 Hidden Terminal Operating Channel: 6, Associated Stations: 1.

- **Additional configurations**
  - All stations have a continuous bidirectional UDP traffic demand of 12Mbps.
  - The hidden terminal's station has a continuous bidirectional 30Mbps traffic demand.

Experimental Evaluation



Experimental Evaluation

Scenario	$\mathcal{DC}_u(\mathcal{F}_c)$	$\mathcal{DC}_a(\mathcal{F}_c)$	$\mathcal{DC}_{\max}$	$\mathcal{MCS}_{ua}$	$\mathcal{C}_{Th}$	$C_{ua} = (1-\mathcal{DC}_{\max}) * \mathcal{C}_{Th}$	C_{ua}^{REAL}
High RSSI (AP1)	87.1%	86.4%	87.1%	23	195 Mbps	25.155 Mbps	27.9 Mbps
Mod. RSSI (AP2)	89.7%	21.4%	89.7%	21	156 Mbps	16.06 Mbps	16.875 Mbps
Low RSSI (AP3)	46.1%	48.2%	48.2%	19	78 Mbps	40.4 Mbps	46.35 Mbps

Observations:

- ✓ Accurate throughput prediction achieved by using the proposed framework.
- ✓ Spectral conditions could be dramatically different between AP and UE at the same frequency. Such great variations could potentially indicate the presence of a hidden terminal.

Association approaches:

- ✓ **(RSSI based *AP1*)** Moderate performance as there is a large number of contending stations associated.
- ✓ **(AP load oriented *AP2*)** Poor performance as a hidden terminal is present on the UE's side.
- ✓ **(Proposed framework *AP3*)** *Jointly considers the overall spectrum utilization with RSSI values obtained and leads to the greater performance*.

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Conclusions

In this work, a novel light-weight mechanism for fast spectral-driven association decisions has been introduced.

- ✓ Completely based on IEEE 802.11 commercial hardware.
- ✓ Entirely developed with open source software.
- ✓ Accurate evaluation of the spectral conditions both at UE's and AP's side.
- ✓ Minimum scanning and processing costs noted from the use of the proposed framework.
- ✓ Significant throughput gains for the offloaded UE have been demonstrated after extensive experimentation.

Thank You!

Kostas Chounos
hounos@uth.gr

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