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Wi-Fi Network Monitoring with GÉANT WiFiMon

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Introduction

WiFiMon: Introduction

- Monitoring Wi-Fi network performance as experienced by end users
- Combination of crowdsourced and hardware probe measurements
- IEEE 802.1X networks (***eduroam***): Data from *RADIUS* and *DHCP* logs strengthen analysis options, e.g. per *Access Point* (*AP*)

Contribution:

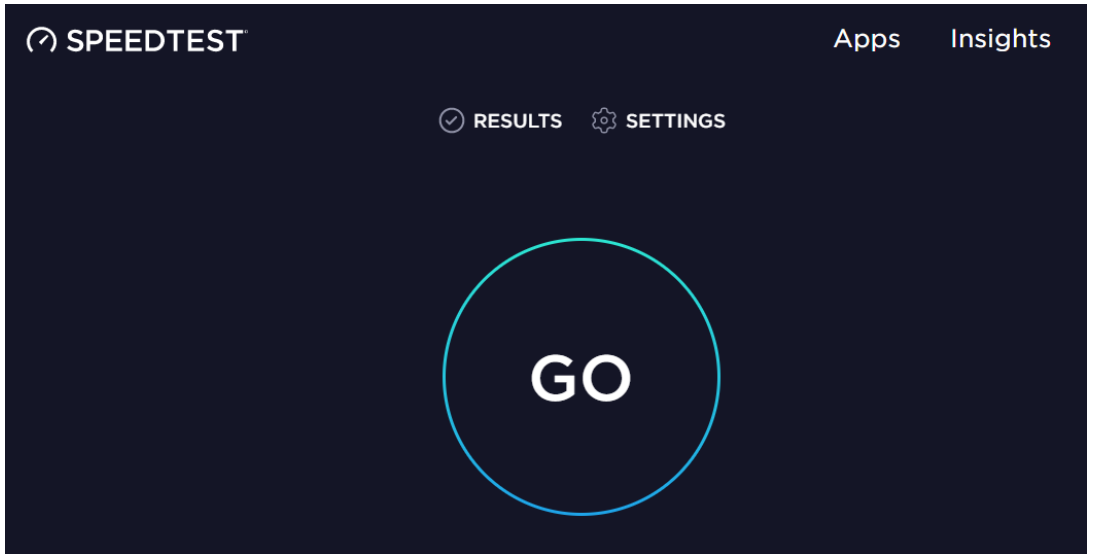
- Detection of Wi-Fi throughput degradation
- Determination of underperforming areas within a Wi-Fi network

→ Admins may enhance performance, e.g. by installing more *AP*s

WiFiMon vs other monitoring solutions:

- Monitoring from the end user perspective (***end user experience***)
- No requirements for end user intervention or installation of apps
- Centralized view of Wi-Fi performance available to the Wi-Fi administrator

Example: *WiFiMon* vs *Ookla Speedtest*



	WiFiMon	*Ookla Speedtest*
Measurements are triggered:	**automatically by visiting a site**	**by pressing “GO”**
Results are collected by:	**the Wi-Fi administrator**	**the end users**

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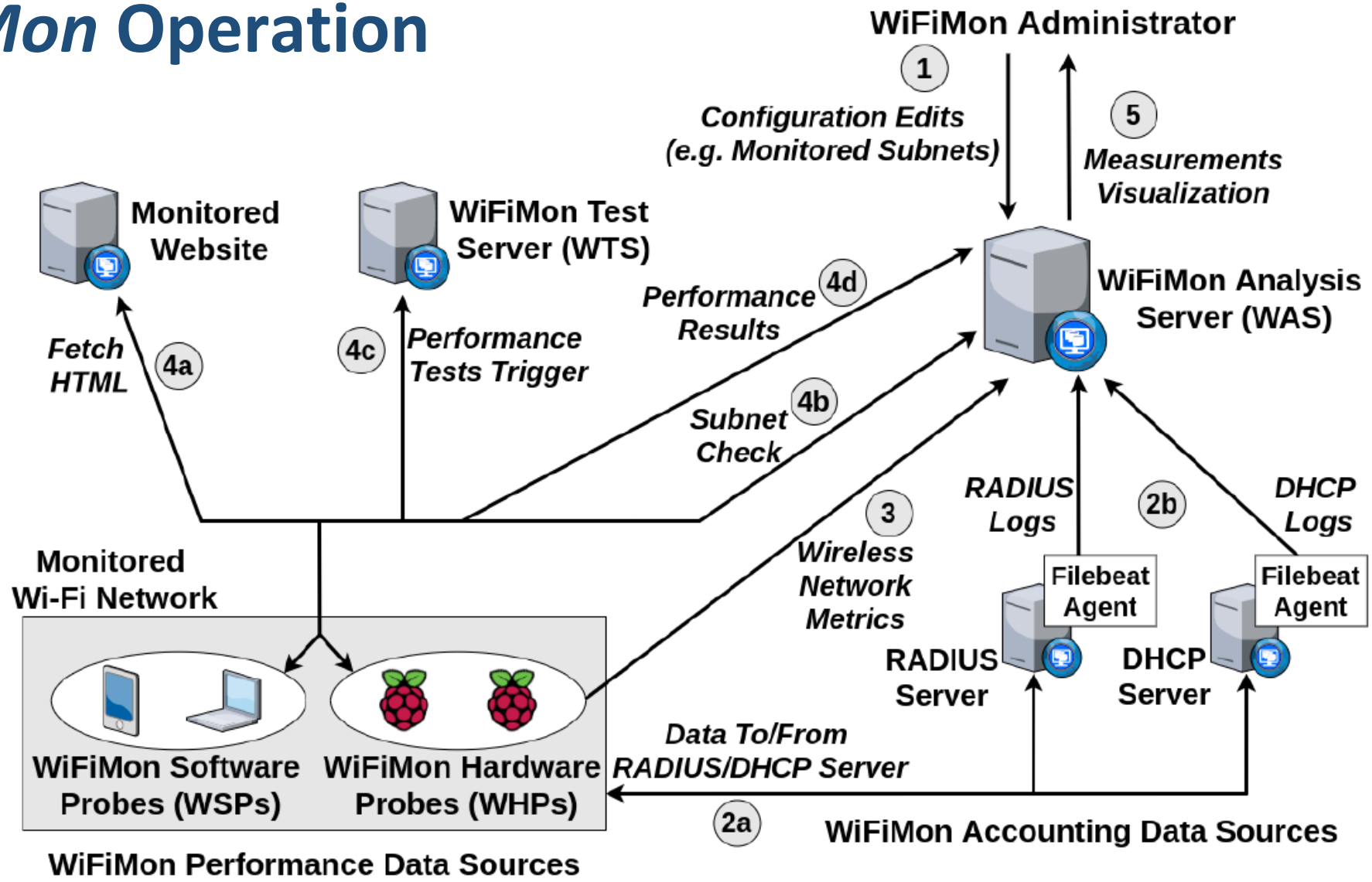
Design Features & Operation

Design Features of *WiFiMon*

- Monitoring based on crowdsourced and/or hardware probe based measurements
- Correlation with *RADIUS* and *DHCP* logs respecting end user privacy
- Independence of Wi-Fi technology and hardware vendor
- Lightweight, active monitoring without impact on end user browsing experience

WiFiMon Operation



WiFiMon Components:

- *WiFiMon Software Probes (WSPs)*
- *WiFiMon Hardware Probes (WHPs)*
- *WiFiMon Test Server (WTS)*
- *WiFiMon Analysis Server (WAS)*

Components

WiFiMon Test Server (WTS)

Purpose: Holds code and test data for performance measurements

- Based on ***JavaScript* (*JS*)** technology
- *HTML* script tags pointing to test tools are added to frequently visited sites
- Measurements of the *HTTP* service (Majority of Internet traffic)

3 available test tools:

→ ***NetTest*** (https://code.google.com/archive/p/nettest/)

→ ***Akamai Boomerang*** (https://github.com/akamai/boomerang)

→ ***LibreSpeed Speedtest*** (https://github.com/librespeed/speedtest)

***WTS* Placement:** Close to monitored networks
(*RTT* between end devices and *WTS* included in results)

→ ***If not possible***: *WiFiMon* captures **relative changes** in Wi-Fi performance

WiFiMon Software Probes (WSPs)

- **User devices** (laptops, smartphones, …)
- Crowdsourced measurements triggered against the *WTS* when users visit a *WiFiMon*-enabled site (**not triggered by end users themselves**)
- No requirement for additional software within user devices
- Repetitive measurements regulated via a cookie value (*WAS*/*WTS* not overloaded)

Example: **Lines for Akamai Boomerang test tool**
(injected in a sample web site)

```
<html>
<head>
<title>Boomerang measurement page</title>
        <script type="text/javascript" src="https://fl-5-205.unil.cloud.switch.ch/wifimon/js/boomerang/jquery-3.5.1.min.js"></script>
        <script type="text/javascript" src="https://www.google.com/jsapi"></script>
        <script src="https://fl-5-205.unil.cloud.switch.ch/wifimon/js/boomerang/boomerang.js" type="text/javascript"></script>
        <script src="https://fl-5-205.unil.cloud.switch.ch/wifimon/js/boomerang/bw.js" type="text/javascript"></script>
        <script src="https://fl-5-205.unil.cloud.switch.ch/wifimon/js/boomerang/rt.js" type="text/javascript"></script>
        <script type="text/javascript" id="settings" hostingWebsite="https" agentIp="fl-5-205.unil.cloud.switch.ch" agentPort="8443"
testtool="boomerang" imagesLocation="https://fl-5-205.unil.cloud.switch.ch/wifimon/images/" cookieTimeInMinutes="0.01"
            src="https://fl-5-205.unil.cloud.switch.ch/wifimon/js/boomerang/boomerang-trigger.js" defer></script>
</head>
<body>

    <h1>Sample https page for WiFiMon measurements using <strong>boomerang</strong></h1>
</body>
</html>
```

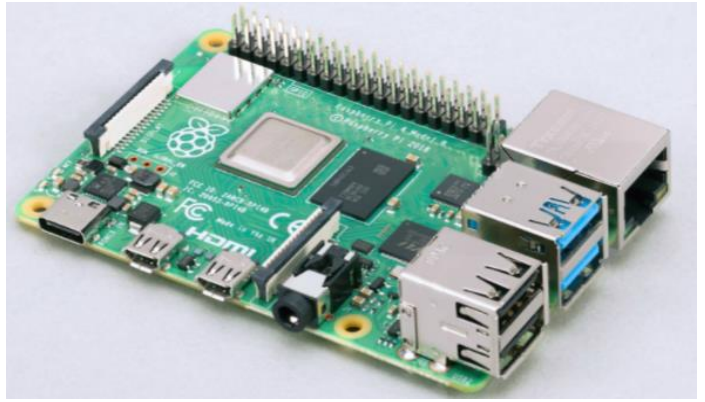
WiFiMon Hardware Probes (WHPs)

- Wi-Fi performance measurements from **fixed points** within the network (distance between *WHP*s and *AP*s is relatively constant)
- Baseline throughput that complements crowdsourced measurements (probes are standalone and can be used without crowdsourced measurements)
- Performance measurements similar to *WSP*s (on predefined intervals)
- Additional data about monitored and nearby *ESSID*'s (*AP*s, signal strength, link quality, bit rate, TX power)

Triggering measurements based on *crontabs*:

```
00,10,20,30,40,50 * * * * Xvfb :100 &
02,12,22,32,42,52 * * * * export DISPLAY=:100 && firefox-esr --new-tab URL_TO_nettest.html >/dev/null 2>&1
04,14,24,34,44,54 * * * * export DISPLAY=:100 && firefox-esr --new-tab URL_TO_speedworker.html >/dev/null 2>&1
06,16,26,36,46,56 * * * * export DISPLAY=:100 && firefox-esr --new-tab URL_TO_boomerang.html >/dev/null 2>&1
08,18,28,38,48,58 * * * * /home/pi/wireless.py >> ~/cron.log 2>&1
```

Tested for Raspberry Pi v3 and v4,
→ Possible for any single-board computer



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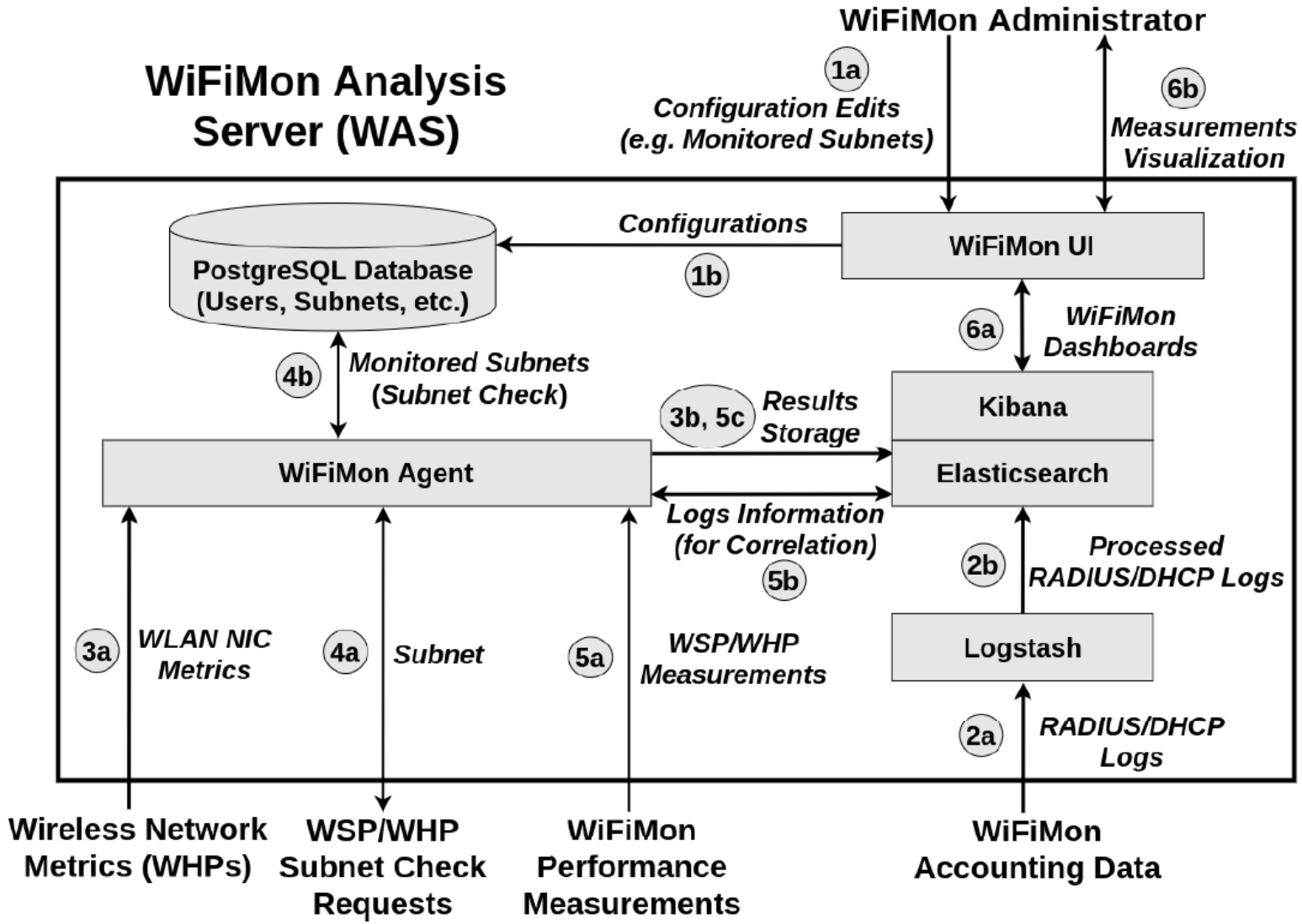
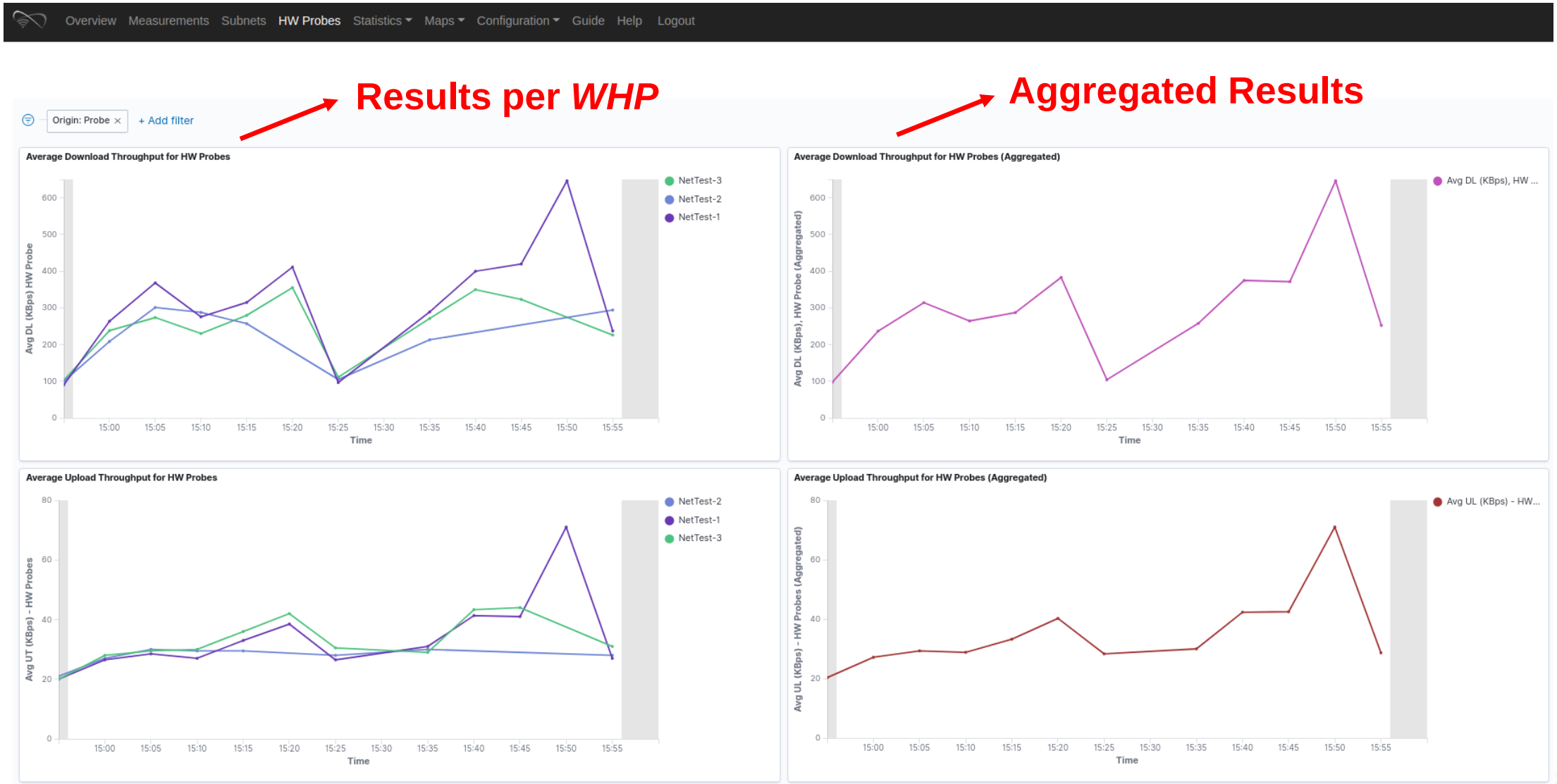
WiFiMon Analysis Server (WAS)



WAS Modules:

- ***WiFiMon Agent*:** Collects and processes the received monitoring data
- ***WiFiMon User Interface (UI)*:** Depicts the results of data processing

WiFiMon User Interface (1)



Results from 3 *WHPs* during a 60-minute interval

WiFiMon User Interface (2)

Dashboards available for:

- Average values
- Median values
- Maximum values
- Minimum values
- 95th Percentile values

Depicting estimations of:

- Download throughput
- Upload throughput
- HTTP ping Round Trip Time (RTT)

That may be:

- Uncorrelated
- Correlated with the available *AP*s

Sources:

- **Crowdsourced measurements**
- **Hardware Probe measurements**

Correlation with *RADIUS/DHCP* Logs

Logs are:

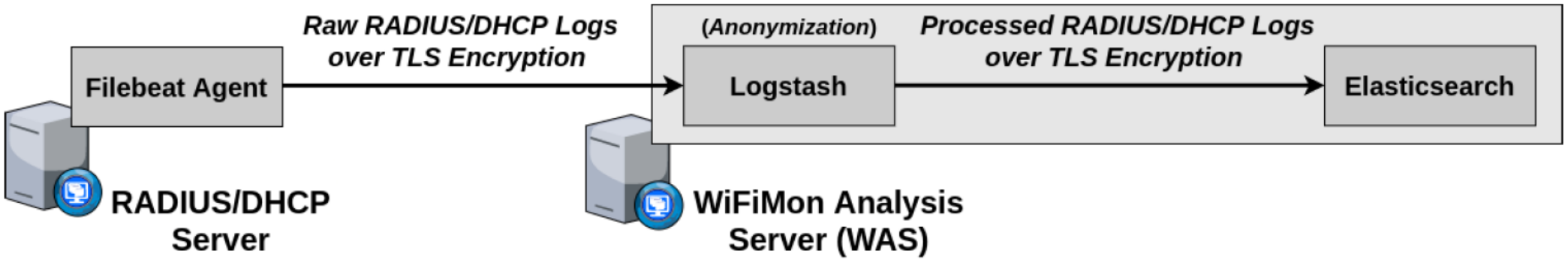
- Extracted from *RADIUS/DHCP* servers using ***Filebeat***
- Processed and transformed by ***Logstash*** in *WAS*
- Stored in ***Elasticsearch*** of *WAS*

Correlation options:

- With end user IP address (relying solely on *RADIUS* logs)
- With end user MAC address (using both *RADIUS* and *DHCP* logs)

Personally Identifiable Information (PII): IP and MAC addresses are secured in transit using a TLS-encrypted channel and stored hashed in *WAS* (based on *X-Pack*)

→ Correlation comparisons are performed on hashed strings.



Other Features of *WiFiMon*

- **Notification of *WiFiMon* version updates**
  - *WiFiMon* Users are informed of new versions from the UI
  - Enables monitoring *WiFiMon* utilization (optional feature)

- **Log Exporter specifically designed for *eduroam***
  - *WHP* data exported towards the JSON collector of *eduroam* (optional)
  - May be used with any JSON collector

- ***WTS* location information**
  - Facilitates using multiple *WTS* instances
  - Monitoring multiple sites with a single *WAS*

Installation

WiFiMon Installation

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Options:

- Institutions install all components **within their premises**
  - **Ansible playbook** for ***WAS*** automated installation
  - Manual installation for *WTS*
  - All data stay within the institution premises
  - Support from *WiFiMon* team for all components

- ***NMaaS*** (more appropriate for testing/trying *WiFiMon*)
  - Another *GÉANT* Service
  - *WiFiMon WAS* instance deployed on *NMaaS*
  - *WTS* installation still required by institutions **(*should be close to the monitored network*)**
  - Support from *WiFiMon* team for interfacing *WTS* and *Dockerized WAS* on *NMaaS*

NMaaS Portfolio

Manual WAS installation: Abandoned by *WiFiMon*

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Ansible WAS Installation

Specs (minimum/recommended):

- 4 CPU cores
- 8 GB / 16 GB RAM
- 10 GB / 50 GB Free Space

Operating Systems Tested:

- Debian 10
- Debian 11
- Ubuntu 18.04
- Ubuntu 20.04

```
wifimon_database_host: localhost
wifimon_database_name: wifimon_database
wifimon_database_user: wifimon_user
wifimon_database_user_pass: wifimonpass
wifimon_admin_email: admin@test.com
wifimon_admin_pass: th1sIs@Secret
# The value of <letsencrypt_admin_mail> variable below must be an real email address
letsencrypt_admin_email: admins@test.com
was_server_hostname: your_was_hostname_here
was_server_domainname: your_domain_name_here.com
# Password for elasticsearch system user
elastic_elasticsearch_password: Elastic_pass_123
# Password for kibana system user
kibana_elasticsearch_password: Kibana_pass_123
# Password for logstash system user
logstash_system_user_password: Logstash_pass_123
# Password for logstash log writer user
logstash_writer_user_password: Logstash_pass_123
# SHA key for encryption of fields in radius/dhcp logs. Please do not use default value
fingerprint_key: 1b34947577646ec59d2ba874c62a90a80759eac0ada9715e
```

Other Requirements:

- Ansible (and its requirements)
- Root access
- Appropriate DNS records
- Filling details (e.g. passwords) within a file (see figure)

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Experience from WiFiMon Pilots

Evaluation

Based on pilots in 2 recent conference venues:

- *TNC19* Conference (Tallinn, 2019)
- *GÉANT* Symposium 2020 (Ljubljana, 2020)

TNC19:

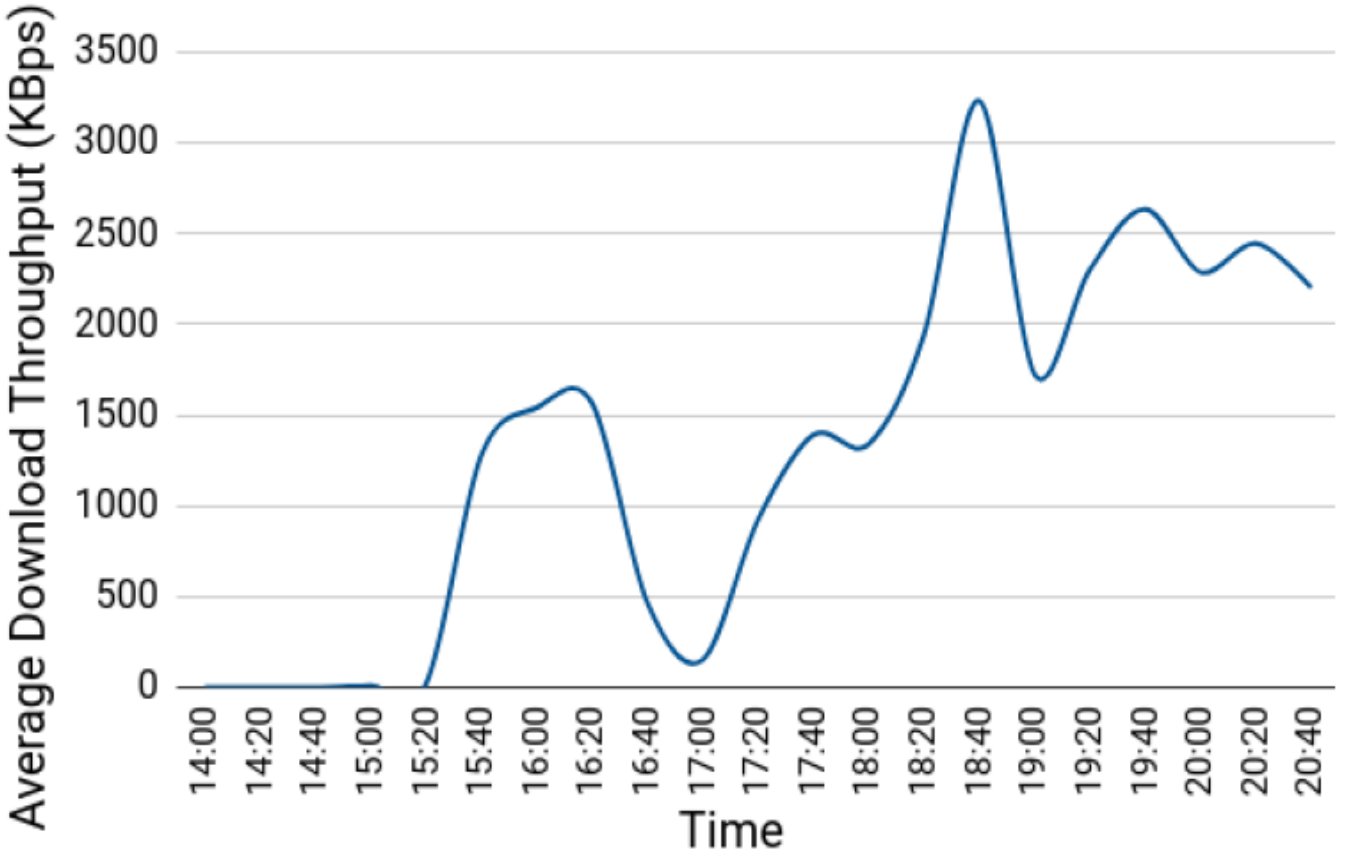
- More than 800 participants
- Monitored Wi-Fi network setup for the conference days
- Monitoring using only *WHP*s (Five Raspberry Pi 3 model B devices)
- *WHP* monitoring interval: 20 minutes
- *WTS* in TalTech: *RTT* between *WTS* and venue less than 4 msec

GÉANT Symposium 2020 :

- Around 250 participants
- Monitored ***eduroam*** ESSID
- *WHP*s: Seven Raspberry Pi 3 model B devices (Interval: 5 minutes)
- Also including *WSP*s: HTML lines in the conference agenda after receiving consent during the online registration process
- *WTS* in *ARNES*, the Slovenian *NREN*

TNC19 Pilot (1)

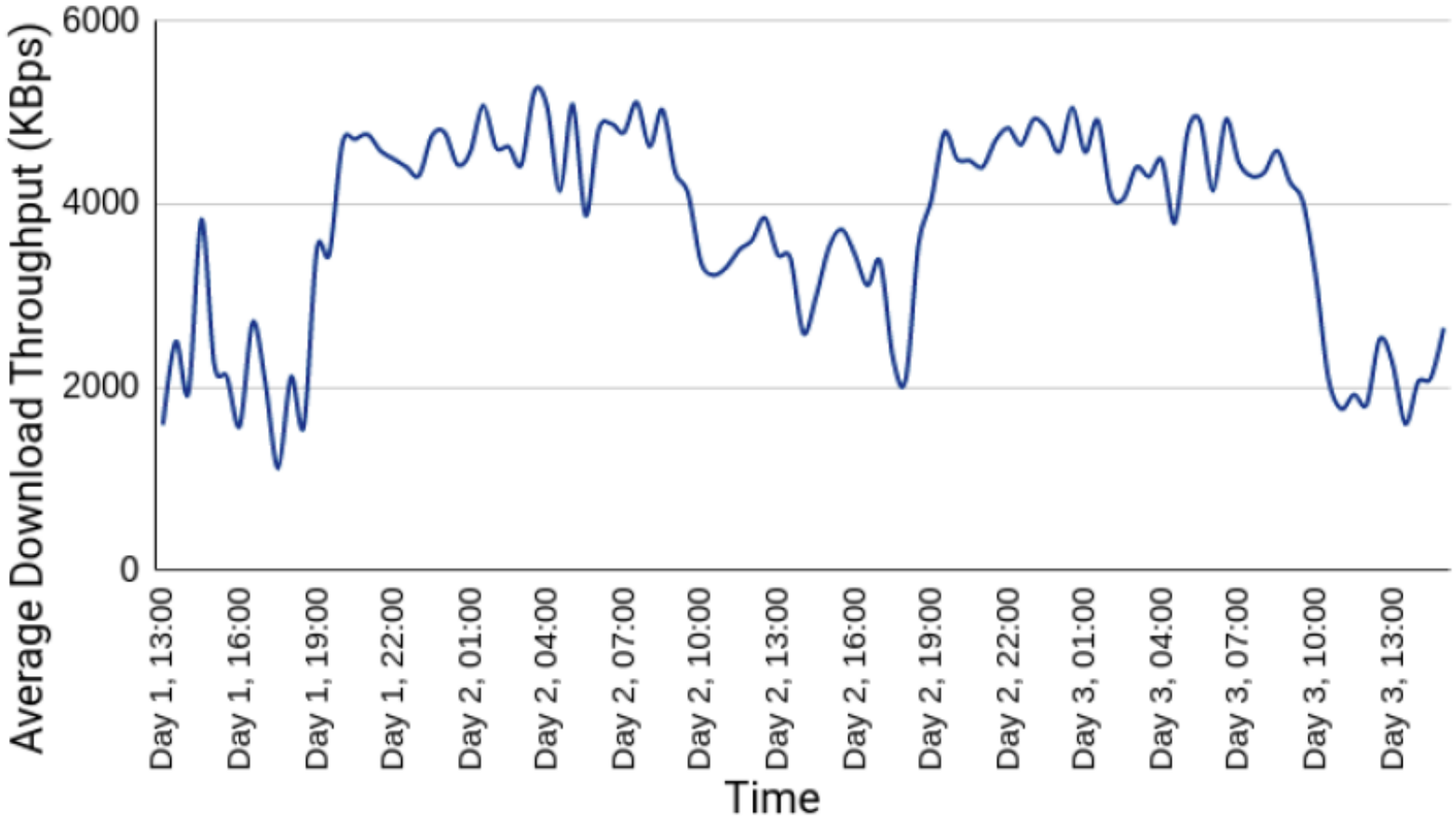
Average download throughput reported by a *WHP* placed in the main hall during the 1st conference day:



- **14:00 – 15:20:** Low throughput and connectivity issues during lightning talks
- **15:20 – 16:30:** Less people in the venue → Higher throughput
- **Around 17:00:** Significant drop because of opening ceremony
- **After 18:00:** Wi-Fi performance restored after people had left the venue

TNC19 Pilot (2)

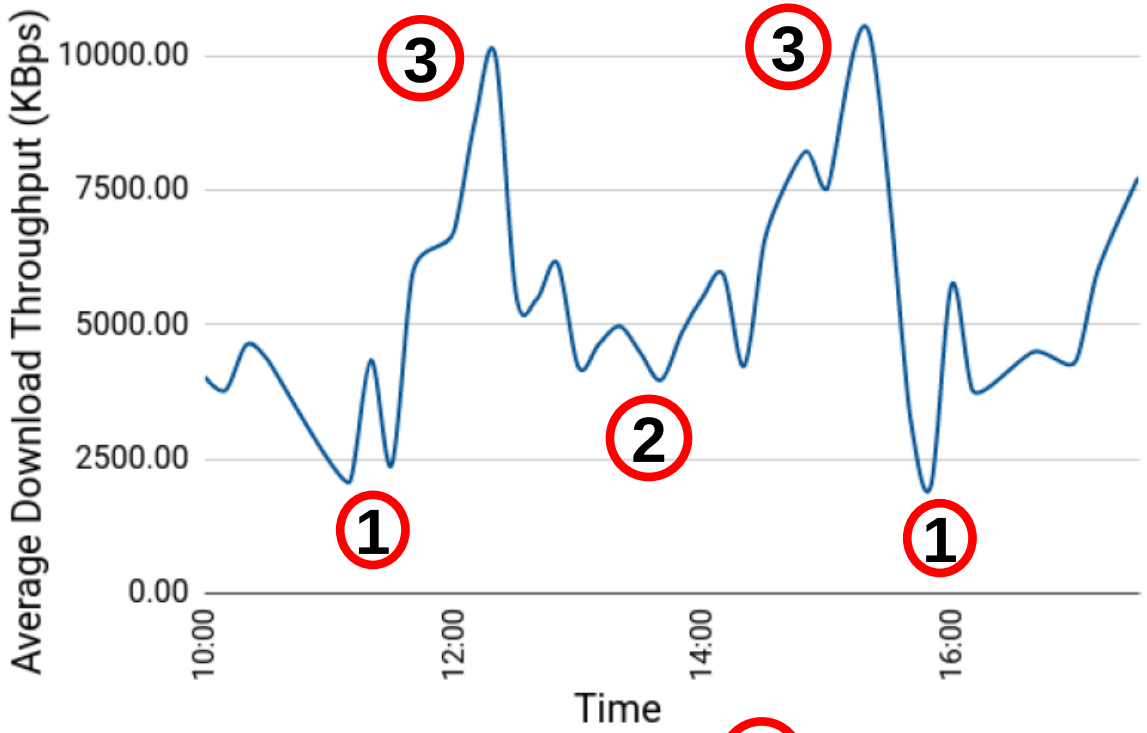
Average download throughput reported by a *WHP* placed in the room where coffee/lunch breaks and the opening ceremony occurred:



Wi-Fi performance degraded when people were at the venue, while the throughput was higher and more stable when participants were absent.

GÉANT Symposium 2020 Pilot (1)

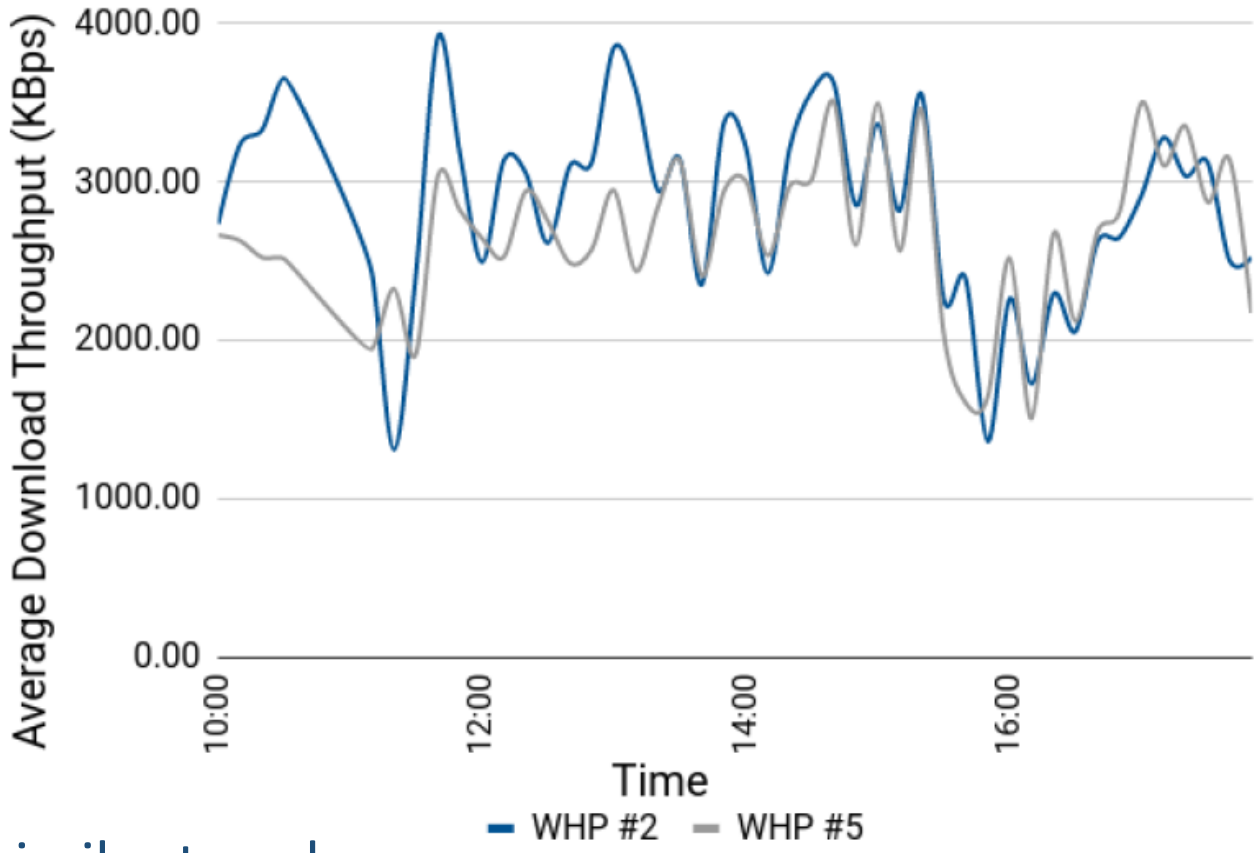
Average download throughput reported by crowdsourced measurements (1st Symposium Day between 10:00 and 17:00):



- **Major drops:** 11:00 – 11:40 and 15:30 – 16:00 (1)
  → Periods after coffee break (more people visiting symposium agenda)
- **Notable drop:** 12:30 – 14:00 (2)
  → During and after lunch time when most participants gathered in less space
- **Higher levels:** Around 12:20 and 15:20 (3)
  → Participants distributed across many different sessions

GÉANT Symposium 2020 Pilot (2)

Average download throughput reported by *WHP*s #2 and #5 (1st Symposium day):



- Both *WHP*s follow similar trends
- Both *WHP*s conceive the throughput drops reported by *WSP* measurements
- *WHP*s reported less throughput as they were placed near the available power plugs, typically farther from *Access Points* than the audience (e.g. on the floor)

GÉANT Symposium 2020 Pilot (3)

WLAN metrics and performance measurements from the 1st Symposium day:

WHP No	Average Signal Level (dBm)	Average Bit Rate (Mbps)	Average Link Quality	Average TX Power (dBm)	Average Download Throughput (KBps)	Average Upload Throughput (KBps)	Average Ping Latency (msec)
1	-43	71	67/70	31	1588	763	48
2	-52	49	58/70	31	2883	1500	30
3	-59	78	51/70	31	2644	1429	44
4	-59	59	51/70	31	1431	650	41
5	-66	75	44/70	31	2678	1514	23
6	-62	65	48/70	31	1758	890	41
7	-55	66	55/70	31	2730	1562	32

Observation: WLAN metric trends may not follow those of performance measurements

- ***WHP* #1: *best*** average link quality, but among the ***worst*** throughput results
- ***WHP* #5: *worst*** average link quality, but among the ***best*** throughput results

Conclusion: Multiple sources of information, i.e. crowdsourced and probe measurements, are vital for proper Wi-Fi performance evaluation

→ High values of signal strength/link quality do not necessarily guarantee high Wi-Fi throughputs

Future Steps and Useful Links

Future Steps

- Additional information from *WHP*s
  - CPU/Memory/Disk info
  - Wi-Fi frequency
  - *TWAMP* protocol measurements

- Additional monitoring tools
  - Research for appropriate *UNIX*-based tools

- Automatic prediction of Wi-Fi performance drops (**Time series analysis**)

- Automatic correlation between crowdsourced and probe measurements

- Support for IPv6

Check out the *WiFiMon* video!

https://www.youtube.com/watch?v=9LuGlF6JSnA

… or the *WiFiMon Infoshare*

https://www.youtube.com/watch?v=VXQV2zWRKgo

… or previous presentations

https://wiki.geant.org/display/WIF/WiFiMon+Publications

… or the WiFiMon paper at IEEE/IFIP WONS 2021

http://dl.ifip.org/db/conf/wons/wons2021/1570695031.pdf

Thank you

Homepage:

https://wiki.geant.org/display/WIF

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