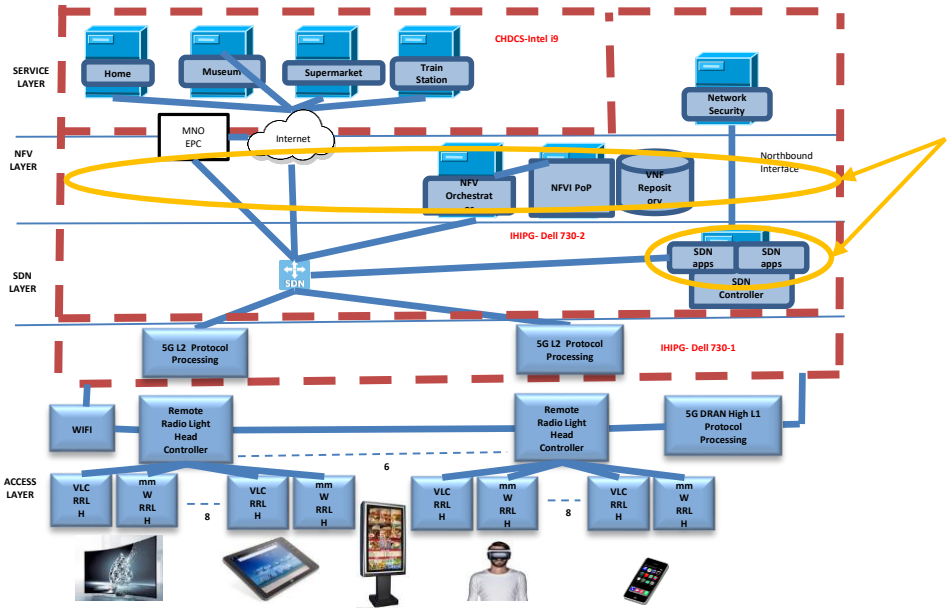
SDN/NFV developments – Load Balancing and Access Point Assignment

Charilaos ZARAKOVITIS
c.zarakovitis@iit.demokritos.gr
National Center for Scientific Research “Demokritos” (NCSRD)

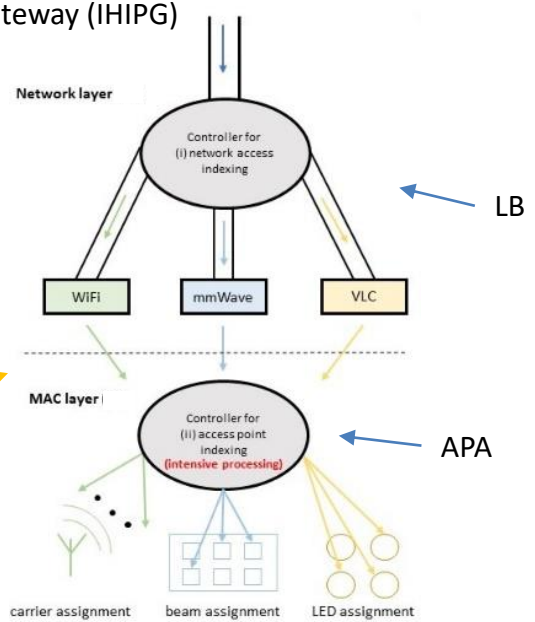
The Load Balancing Process

- **What is it:** a process to distribute traffic across co-existing networks
- **The IoRL LB:** is a mechanism to switch traffic among the VLC, mmWave and Wi-Fi networks that co-exist in the IoRL system
- **Implementation:** developed in the form of VNF,
  integrated within the SDN/NFV environment of the IoRL Intelligent Home IP Gateway (IHIPG)



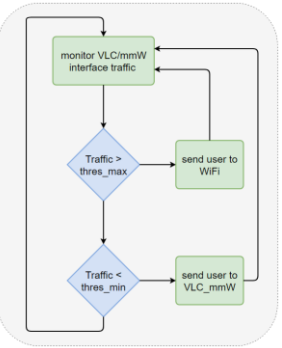
Placement within the system

Stand-alone viewpoint (impact on the IoRL L3 and L2 architecture)

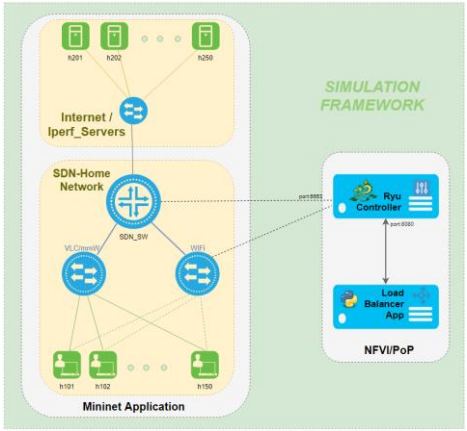


Process overview

The Load Balancing Process



Flow diagram of the Ryu controller including application of load balancing



Topology of the modelling

- The **Mininet** application is used to simulate the home network topology including the WiFi and VLC/mmW deployment

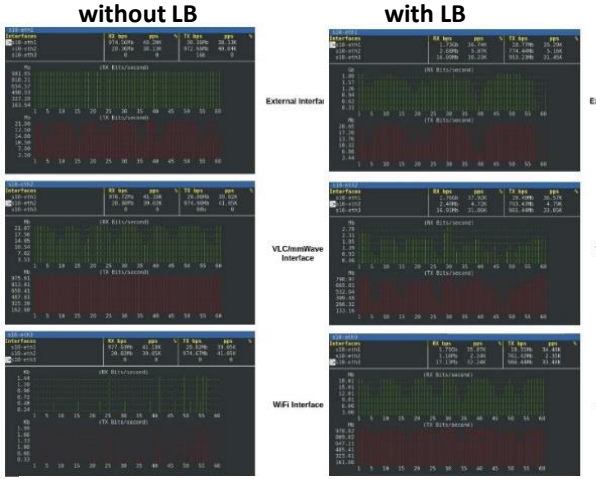
  It includes:
  - → 4 SDN switches (deployed)
  - → 50 pairs of virtual iperf servers/clients (deployed)
  - → each client requests different random load

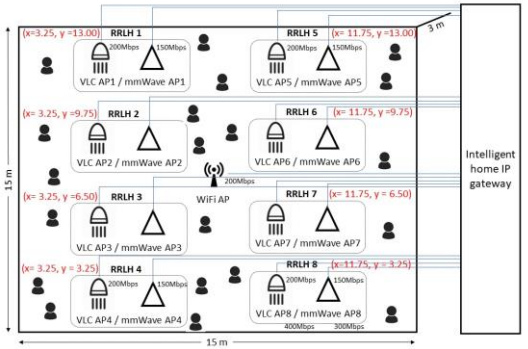
- The **Ryu controller** is responsible for installing the flows/routes at the SDN switches

  It includes:
  - → Initialisation of the flows of each SDN switch
  - → Monitoring of the traffic over both VLC/mmW and WiFi interfaces
  - → Implementation of Restful API for remote communication and configuration

- **Load balancer application**

  It includes:
  - → Restful API to communicate with Ryu
  - → Tracking mechanisms for connecting users to VLC/mmWave and WiFi networks
  - → Mechanism to install new/customized data-flows



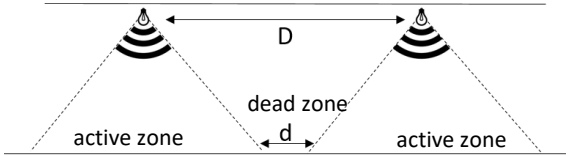


The Access Point Assignment Process (APA)

- **What is it:** a process to distribute traffic across co-existing Access Points (APs) of heterogeneous networks

- **Why to consider:** … the IoRL VLC and mmWave Access Points (APs) can cover relatively small areas of approximately 2-3 meters diameter, while the WiFi AP can access the, so-called, "dead zones", where the light and beams cannot spread …

- **Observation:** … when compared to VLC, a WiFi AP has a much larger coverage range (i.e. up to 40 meters indoor) but less network capacity (i.e. x10 lower throughput) …



- **The IoRL APA:** is a mechanism to balance the coverage-vs-capacity of the IoRL system …
  … by associating the users located into dead-zones to the WiFi APs …
  … while keeping the rest of the users connected to the VLC and mmWave networks …
  … and by considering the minimum QoS requirements of these users …

- **Implementation:** delivered in the form of VNF → as an upgrade of the IoRL LB VNF, integrated within the SDN/NFV environment of the IoRL Intelligent Home IP Gateway (IHIPG)

Produced publications:

S. F. Chien, C. C. **Zarakovitis**, Q. Ni and P. Xiao, "Stochastic Asymmetric Blotto Game Approach for Wireless Resource Allocation Strategies," in ***IEEE Transactions on Wireless Communications***, vol. 18, no. 12, pp. 5511-5528, Dec. 2019, doi: 10.1109/TWC.2019.2936853.

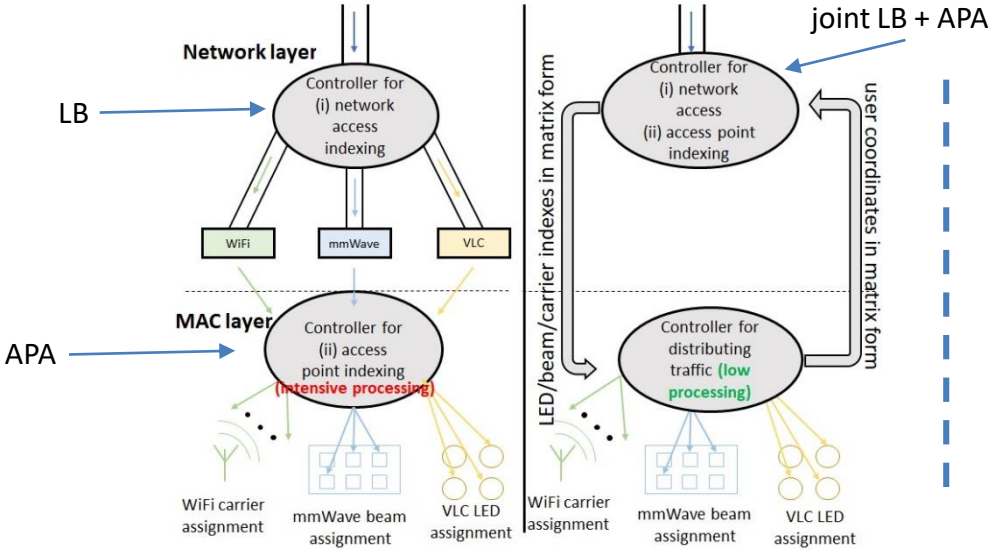
C. **Zarakovitis** *et al*., "A SDN-based WiFi-VLC Coupled System for Optimised Service Provision in 5G Networks," ***IEEE International Symposium on "A World of Wireless, Mobile and Multimedia Networks" (WoWMoM)***, Chania, 2018, pp. 14-17, doi: 10.1109/WoWMoM.2018.8449747.

C. C. **Zarakovitis** *et al*., "Three-dimensional Access Point Assignment in Hybrid VLC, mmWave and WiFi Wireless Access Networks," *ICC 2020 - **2020 IEEE International Conference on Communications (ICC)***, Dublin, Ireland, 2020, pp. 1-6, doi: 10.1109/ICC40277.2020.9148722.

The Access Point Assignment Process (APA)

Novelties:

1) Conventional APA processes showcase intensive processing at the MAC layer (left)
The proposed APA approach is SDN-oriented → takes place a the SDN controller 3
→ low processing at the MAC layer (right).



$$\max_{\hat{S}_{inwj}\in\{0,1\}} R=\sum_{j=1}^{K} R_j^{\text{VLC/mmWave/WiFi}}$$

subject to:

$$(C1)\ \sum_{j=1}^{K} q_j^{\text{Class}(\varepsilon)}=1,$$

$$(C2)\ R_j^{\text{VLC/mmWave/WiFi}} \geq \text{QoS}_j^{\min},\ \forall j,$$

$$(C3)\ \sum_{j=1}^{K} S_{inwj} \leq 1,\ \forall i,n,w,$$

$$\tilde{S}^{*}_{inwj}=\left(\frac{2}{K}-3\cdot\overline{SNR}^{(\cdot)}_{inwj}\cdot\left(\sqrt{1+\frac{8}{9\cdot K\cdot\overline{SNR}^{(\cdot)}_{inwj}}}-1\right)\right)\Big/\left(3\cdot\sqrt{1+\frac{8}{9\cdot K\cdot\overline{SNR}^{(\cdot)}_{inwj}}}-1\right)$$

$$R_j^{\text{VLC/mmWave/WiFi}}=q_j^{\text{Class}(\varepsilon)}\cdot\sum_{i=1}^{I}\sum_{n=1}^{N}\sum_{w=1}^{W}\hat{S}_{inwj}\Big[BW^{\text{VLC}}\cdot\log_2\left(1+SNR_{inwj}^{\text{VLC}}\right)$$

$$+BW^{\text{mmWave}}\cdot\log_2\left(1+SNR_{inwj}^{\text{mmWave}}\right)+BW^{\text{WiFi}}\cdot\log_2\left(1+SNR_{inwj}^{\text{WiFi}}\right)\Big]$$

3-dimensional optimisation operand →

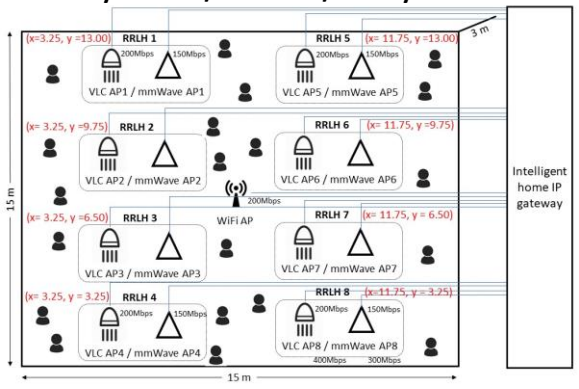
$$[\mathbf{S}_{I\times N\cdot W}]_j=\left[\hat{S}_{inw}\right]_j=\begin{bmatrix}\begin{bmatrix}\hat{S}_{111} & \cdots & \hat{S}_{1n1}\\ \vdots & \ddots & \vdots\\ \hat{S}_{i11} & \cdots & \hat{S}_{in1}\end{bmatrix}\\ \begin{bmatrix}\hat{S}_{112} & \cdots & \hat{S}_{1n2}\\ \vdots & \ddots & \vdots\\ \hat{S}_{i12} & \cdots & \hat{S}_{in2}\end{bmatrix}\\ \begin{bmatrix}\hat{S}_{11w} & \cdots & \hat{S}_{1nw}\\ \vdots & \ddots & \vdots\\ \hat{S}_{i1w} & \cdots & \hat{S}_{inw}\end{bmatrix}\end{bmatrix}_j$$

→ Final formula of optimal APA

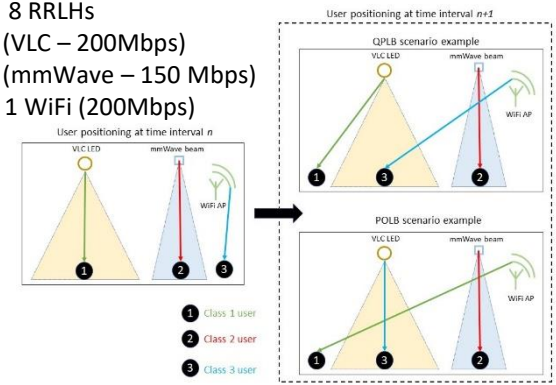
2) Conventional APA processes consider two-RAT system structures i.e., either VLC-vs-WiFi, VLC-vs-mmWave or mmWave-vs-WiFi
The proposed APA considers three-RAT hybrid network modelling, i.e., joint VLC-vs-mmWave-vs-WiFi
→ optimal AP assignment points can be determined is leveraged from two-dimensional (2D) to three-dimensional (3D) space
→ More complex (yet more concise) problem formulation
→ non-conventional solution method to resolve (complexity/accuracy/convergence)
→ Resolved via standard Lagrangian optimization (avoid duality)

The joint Load balancing and Access Point Assignment (APA) Process

The hybrid VLC/mmWave/WiFi system model



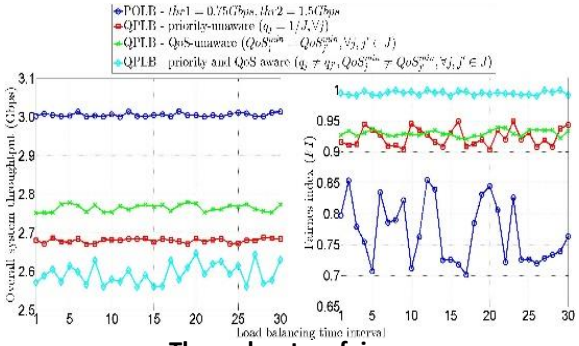
→ 8 RRLHs
(VLC – 200Mbps)
(mmWave – 150 Mbps)
→ 1 WiFi (200Mbps)



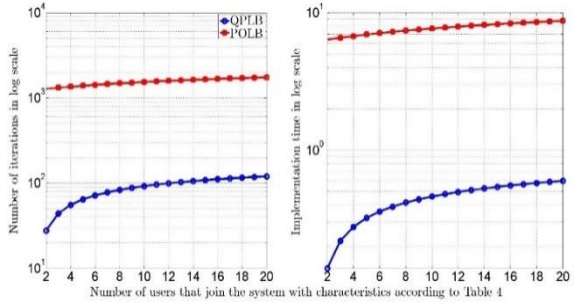
Normalised VLC and mmWave channel gains w.r.t the user positions (in dBm)

	u	Conventional PO2A VLC_LED	Conventional PO2A mmWave beam	u	Proposed QP3A VLC_LED	Proposed QP3A mmWave beam
Class 3 (Low)	1	00001000	00000000	1	00000000	00001000
	2	00000100	00000000	2	00000000	00000000
	3	00000000	00000000	3	00000000	00000000
	4	00000000	00000001	4	00000000	00000100
	5	00010000	00000000	5	00000000	00000000
	6	00000000	00010000	6	00000000	00010000
	7	10000000	00000000	7	00000000	00000000
Class 2 (Medium)	8	00000010	00000000	8	00000010	00000000
	9	00000000	00000100	9	00000000	00000001
	10	00000000	00000000	10	00000100	00000000
	11	00100000	00000000	11	00000000	01000000
	12	00000000	00000000	12	00000000	00100000
Class 1 (High)	13	00000001	00000000	13	00000000	00000010
	14	00000000	10000000	14	00000000	10000000
	15	00000000	00000010	15	00010000	00000000
	16	00000000	01000000	16	10000000	00000000
	17	00000000	00001000	17	00100000	00000000
	18	01000000	00000000	18	00000001	00000000
	19	00000000	00000100	19	00001000	00000000
	20	00000000	00000000	20	01000000	00000000

Note: the WiFi channel gains vary between -11 and -13 dBm, yet as WiFi carriers are 4096 in total their channel gains are difficult to represent



Throughput-vs-fairness



Implementation time

Acknowledgement and disclaimer

- This work has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 761992, project IoRL.

- This presentation reflects the author's view, only, and the Commission is not responsible for any use that may be made of the information provided.

Thank you for your attention

<c.zarakovitis@iit.demokritos.gr>

https://iorl.5g-ppp.eu/