NFV Orchestration in Edge and Fog Scenarios

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Outline

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Location of BSs:

- Neyman-Scott Poisson Cluster Process [9]
- Poisson Point Processes (PPPs) [2]
  - homogeneous [10, 1]
  - hard-core [5]

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Location of MEC PoPs:

- along highways [11]
- within stadiums [4]

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Location of MEC PoPs:

- along highways [11]
- within stadiums [4]
- population census
- access & aggregation rings

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1 Generation of 5G infrastructure graphs
- State of the art
- Thesis contributions
- Output

2 NFV Orchestration in federated environments

3 NFV orchestration for 5G networks

4 Scaling of V2N services: a study case

5 Future work

Derive:

- BS location
- MEC PoP location

Meet:

- Tactile RTT of **1 ms**

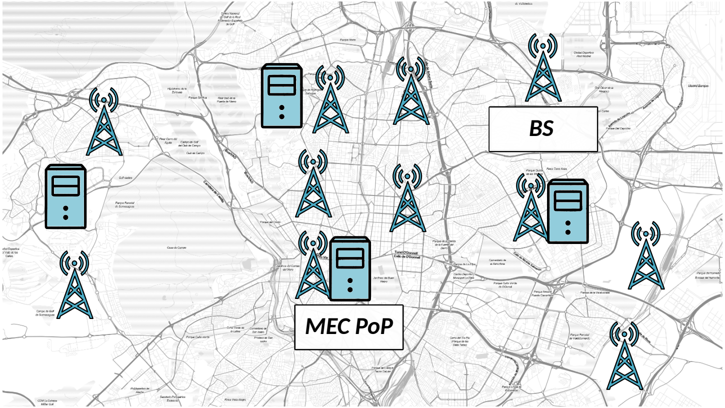

Figure 1: BS and MEC PoP locations

Higher gentrification $\implies$ more BSs

- $f_i(x)$ – revolution func.
- $G(x)$ – gentrification
- R – region of interest
- C_i – area

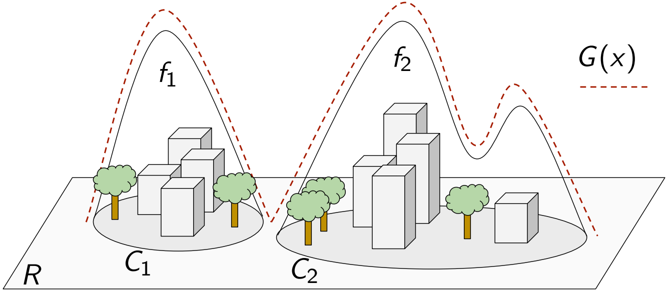

Figure 2: *Revolution functions* of a region with two building areas.

BS intensity function $\lambda(x) \sim G(x)$ proportional to gentrification.

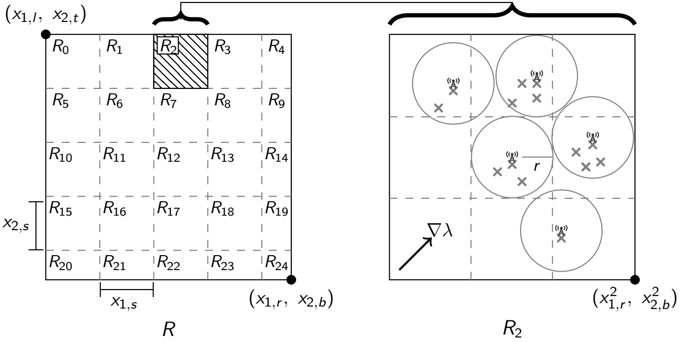

Figure 3: Gridded region (left), and inhomogeneous Mattérn II process of BSs (right).

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- $G(x)$: Madrid census
- R: Madrid city
- Inhomogeneous Mattern II PPs

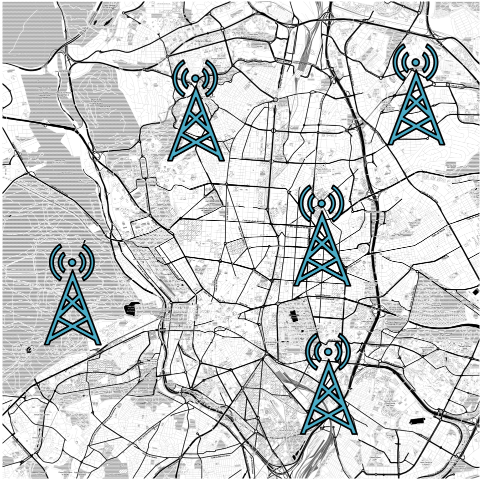

Figure 4: Location of BSs

- $G(x)$: Madrid census
- R: Madrid city
- Inhomogeneous Mattern II PPs

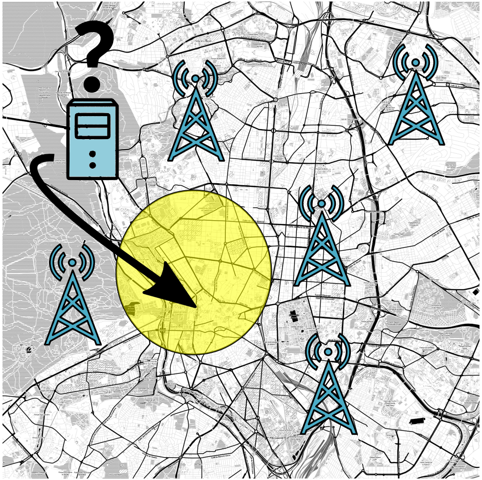

Figure 4: Location of BSs

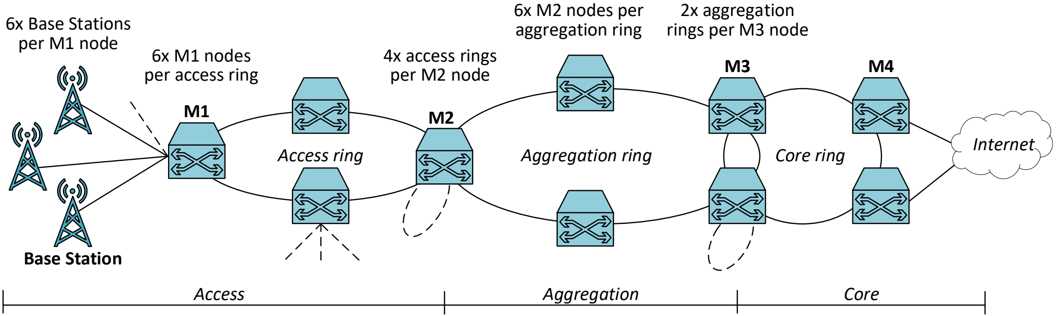

Figure 5: Reference network infrastructure as illustrated[1] in [3] and based on [6].

[1]Author: Dr. Luca Cominardi.

Derive MEC PoP location considering:

$$RTT = \underbrace{2d \cdot 5\frac{\mu s}{km}}_{\text{fiber propagation}} + 2M \cdot 50\mu s + UL + DL \tag{1}$$

- d: distance between BS and MEC PoP
- M: network ring
- UL: Uplink propagation latency
- DL: Downlink propagation latency

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Derive MEC PoP location considering:

$$RTT = 2d \cdot 5\frac{\mu s}{km} + \underbrace{2M \cdot 50\mu s}_{\text{ring propagation}} + UL + DL \qquad (1)$$

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Derive MEC PoP location considering:

$$RTT = 2d \cdot 5\frac{\mu s}{km} + 2M \cdot 50\mu s + \underbrace{UL + DL}_{\text{radio propagation}} \quad (1)$$

- d: distance between BS and MEC PoP
- M: network ring
- UL: Uplink propagation latency
- DL: Downlink propagation latency

m_M: maximum distance between MEC PoP at ring M and BS

Figure 6: How to select MEC PoP location

m_2: maximum distance between MEC PoP at ring 2 and BS

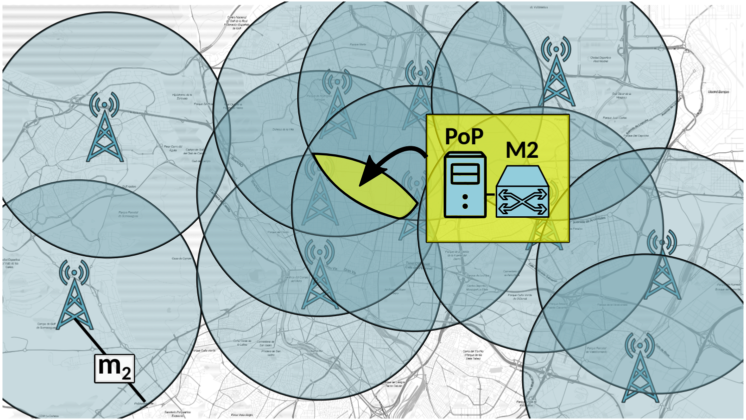

Figure 6: How to select MEC PoP location

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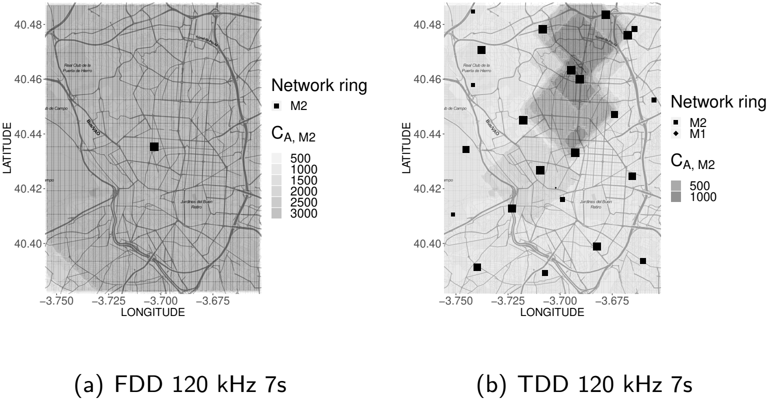
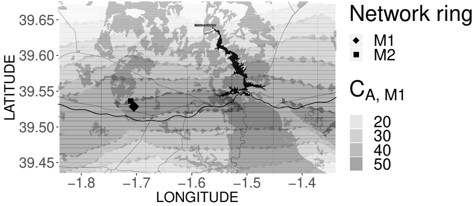
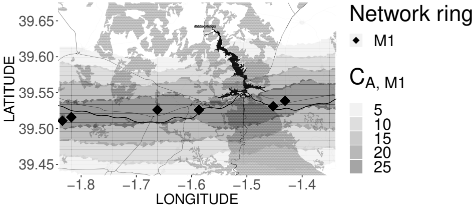


Figure 7: **Urban scenario** (Madrid city center) – $C_{A,M2}$ =covered BSs



(a) FDD 120 kHz 7s



(b) TDD 120 kHz 7s

Figure 8: **Highway scenario** (Hoces del Cabriel A3) – $C_{A,M1}$ =covered BSs by M1 MEC PoP

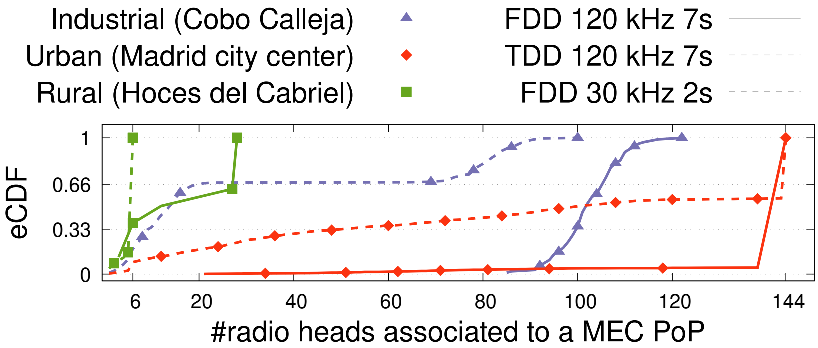


Figure 9: eCDF of the number of BSs assigned to a MEC PoP in the studied scenarios.

Publications

- **Martín-Pérez, Jorge** et al. "Modeling Mobile Edge Computing Deployments for Low Latency Multimedia Services". In: *IEEE Transactions on Broadcasting* 65.2 (2019), pp. 464–474. DOI: 10.1109/TBC.2019.2901406
- **Martín-Pérez, Jorge** et al. "5GEN: A tool to generate 5G infrastructure graphs". In: *2019 IEEE Conference on Standards for Communications and Networking (CSCN)*. 2019, pp. 1–4. DOI: 10.1109/CSCN.2019.8931334

Open-source

- `github.com/MartinPJorge/mec-generator`
- 5GEN R package

Vertical services (VS) contain:

- Virtual Network Functions (**VNFs**); and
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- integrate OKpi with RoS[2]
- migration of robot remote driving component with OKpi

[2]robotic operating system

Thanks for your attention!

OKpi is open-source, and it is implemented in python's placement module as FPTASMapper:

`https://github.com/MartinPJorge/placement`

[1] M. Afshang and H. S. Dhillon. "Poisson Cluster Process Based Analysis of HetNets With Correlated User and Base Station Locations". In: *IEEE Transactions on Wireless Communications* 17.4 (Apr. 2018), pp. 2417–2431. ISSN: 1536-1276. DOI: 10.1109/TWC.2018.2794983.

[2] A. Baddeley, C. internazionale matematico estivo, and W. Weil. *Stochastic Geometry: Lectures Given at the C.I.M.E. Summer School Held in Martina Franca, Italy, September 13-18, 2004*. Lecture Notes in Mathematics / C.I.M.E. Foundation Subseries. Springer, 2007. ISBN: 9783540381747.

[3] L. Cominardi et al. "Understanding QoS Applicability in 5G Transport Networks". In: *2018 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB)*. June 2018, pp. 1–5. DOI: 10.1109/BMSB.2018.8436847. URL: https://e-archivo.uc3m.es/bitstream/handle/10016/27393/understanding_BMSB_2018_ps.pdf (visited on 01/10/2019).

[4] V. Frascolla et al. "5G-MiEdge: Design, standardization and deployment of 5G phase II technologies: MEC and mmWaves joint development for Tokyo 2020 Olympic games". In: *2017 IEEE Conference on Standards for Communications and Networking (CSCN)*. Sept. 2017, pp. 54–59. DOI: 10.1109/CSCN.2017.8088598.

[5] A. M. Ibrahim, T. ElBatt, and A. El-Keyi. "Coverage probability analysis for wireless networks using repulsive point processes". In: *2013 IEEE 24th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*. Sept. 2013, pp. 1002–1007. DOI: 10.1109/PIMRC.2013.6666284.

[6] ITU-T. *Consideration on 5G transport network reference architecture and bandwidth requirements*. Study Group 15 Contribution 0462. International Telecommunication Union - Telecommunication Standardization Sector (ITU-T), Feb. 2018.

[7] **Martín-Pérez, Jorge** et al. "5GEN: A tool to generate 5G infrastructure graphs". In: *2019 IEEE Conference on Standards for Communications and Networking (CSCN)*. 2019, pp. 1–4. DOI: 10.1109/CSCN.2019.8931334.

[8] **Martín-Pérez, Jorge** et al. "Modeling Mobile Edge Computing Deployments for Low Latency Multimedia Services". In: *IEEE Transactions on Broadcasting* 65.2 (2019), pp. 464–474. DOI: 10.1109/TBC.2019.2901406.

[9] V. Suryaprakash, J. Møller, and G. Fettweis. "On the Modeling and Analysis of Heterogeneous Radio Access Networks Using a Poisson Cluster Process". In: *IEEE Transactions on Wireless Communications* 14.2 (Feb. 2015), pp. 1035–1047. ISSN: 1536-1276. DOI: 10.1109/TWC.2014.2363454.

[10] V. Suryaprakash, P. Rost, and G. Fettweis. "Are Heterogeneous Cloud-Based Radio Access Networks Cost Effective?" In: *IEEE Journal on Selected Areas in Communications* 33.10 (Oct. 2015), pp. 2239–2251. ISSN: 0733-8716. DOI: 10.1109/JSAC.2015.2435275.

[11] M. Syamkumar, P. Barford, and R. Durairajan. “Deployment Characteristics of "The Edge" in Mobile Edge Computing”. In: *Proceedings of the 2018 Workshop on Mobile Edge Communications*. MECOMM'18. Budapest, Hungary: ACM, 2018, pp. 43–49. ISBN: 978-1-4503-5906-1. DOI: 10.1145/3229556.3229557. URL: http://doi.acm.org/10.1145/3229556.3229557.

Lemma

Given an inhomogeneous marked PPP X with intensity function λ, the thinning function l_2, and marks $m \sim \frac{1}{\lambda(x)}$, the resulting thinned point process, called inhomogeneous Matérn II PP, has the following average number of points at C:

$$\mathbb{E}\left[N(C)\right] := \int_C e^{-\int_{B(x,r)} \mathbb{1}(\lambda(u) > \lambda(x))\lambda(u)du} \lambda(x)\ dx \tag{2}$$

where r is the thinning radius of l_2.

with

$$l_2(x, m, X, M_X) := \begin{cases} 1 & \text{if } m = \min_{m' \in M_X} \left\{(x', m') : x' \in B(x, r)\right\} \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

The RTT considered is computed as

$$RTT := 2l\left(\|x - m\|_1\right) + 2p(M) + UL + DL \tag{4}$$

We find m_M, the maximum distance from MEC PoP m to the BS at position x, as:

$$\|x - m\|_1 \leq l^{-1}\left(\frac{RTT - 2p(M) - t_r}{2}\right) = m_M \tag{5}$$

with $\|\cdot\|_1$ denoting the Manhattan distance.