

5GEN: A tool to generate 5G infrastructure graphs

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- 1 Introduction
- 2 Motivation
- 3 Generating the graphs
- 4 Use case
- 5 Conclusions

A R package¹ to generate 5G network infrastructure graphs.

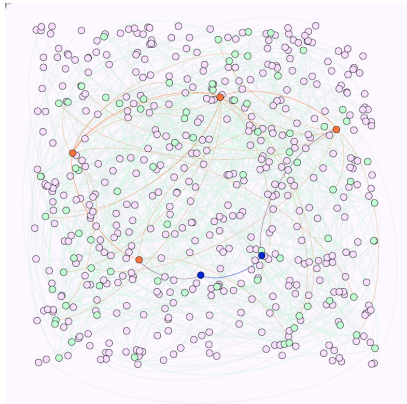


Figure 1: A graph generated by 5GEN.

¹<https://github.com/MartinPJorge/mec-generator/tree/5g-infra-gen>

The network infrastructure **up to the core**.

- Active Antenna Units (AAUs);
- M1, M2 and M3 switches;
- Servers; and
- Fog nodes

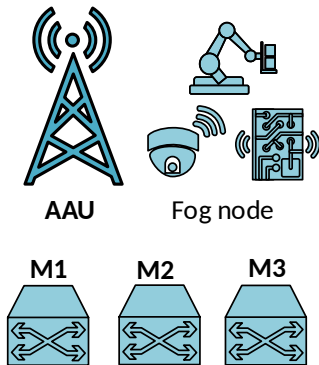


Figure 2: Some 5GEN graph components

To validate solutions for the Virtual Network Embedding (VNE) problem:

“The problem of embedding virtual networks in a substrate network” ([1])

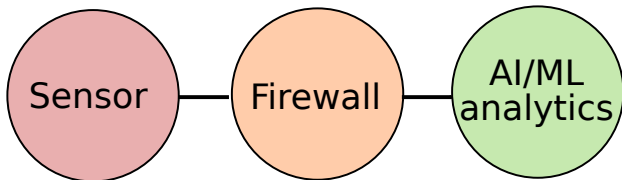


Figure 3: VNE example

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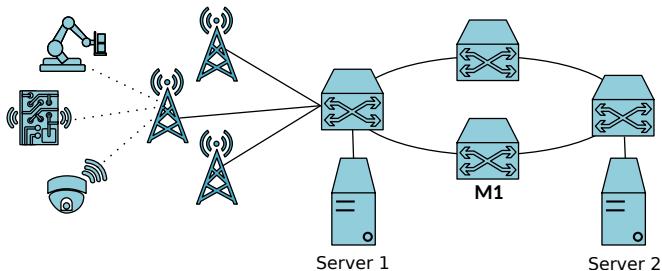


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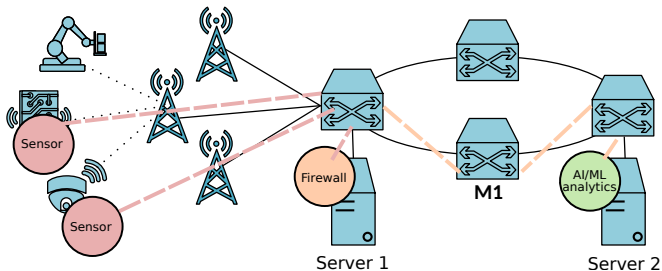


Figure 3: VNE example

Open questions:

- AAUs per switch?;
- Switches per “level”?;
- Interconnections; and
 - Hierarchical;
 - Ring; and
 - Redundancy;
- Traffic rates;

Use analysis in [2], based on ITU-T study group analysis [3]

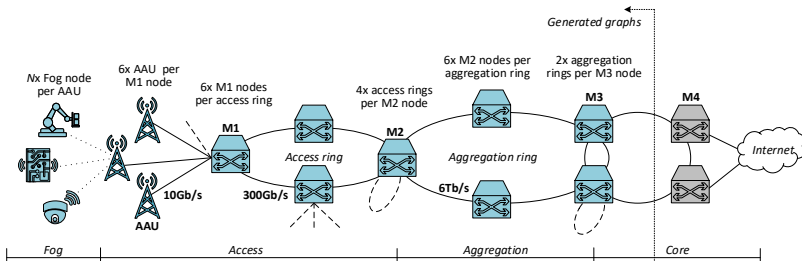


Figure 4: 5GEN reference topologies

- 1 Specify AAUs' locations;
- 2 Calculate required M1 switches and access rings;
- 3 Calculate required M2 switches and aggregation rings;
- 4 Derive how many M3 switches; and
- 5 Attach user-defined elements:
 - Fog devices;
 - Servers & where (M1, M2, M3);

5GEN assumes a set of AAUs distributed across an area, e.g., Granada.



Figure 5: Location of an APU in Granada

```
1 granadaCells[1,]$lat; granadaCells[1,]$lon  
2 [1] 37.1716524  
3 [2] -3.5932497
```

CSV with AAUs locations at

<https://github.com/MartinPJorge/cscn19/blob/master/granada-cells.csv>

- 12 AAUs/km²
- 10m repulsion radius

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

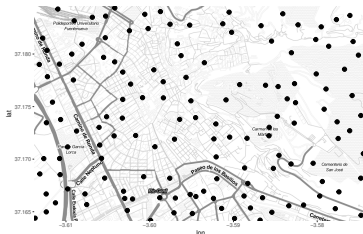


Figure 6: AAUs generated with a Matérn II PPP [4]

```

Data: AAUs
Result: access and aggregation graph
1 levels = [AAUs, access, aggregation];
2 distances = [10km, 20km, 40km];
3 foreach (l, d) in (levels, distance) do
4

$$N = \begin{cases} AAUs, & \text{if } l = \text{AAUs} \\ M1, & \text{if } l = \text{access} \\ M2, & \text{if } l = \text{aggregation} \end{cases}$$

5 H = hierarchical_clustering(N);
6 C = cut_dendrogram(H, d);
7  $R = \cup_{C' \in C} \left\{ \left\{ C'_{i+6j} \right\}_{j=0}^{\min\{C'-1-6j, 5\}} \right\}^{\lfloor C'/6 \rfloor};$ 
8 if l = AAUs then
9   for  $R_j \in R$  do
10      $M1_n = \min_{M1} \sum_{r \in R_j} \text{Vicenty}(M1, r);$ 
11     connect( $r, M1_n$ ),  $\forall r \in R_j;$ 
12   end
13 else
14   connect( $r_i, r_{i+1 \bmod 6}$ ),  $\forall r_i \in R_j, \forall R_j \in R;$ 
15    $g = 4$  if  $l = M1$  else 2;
16    $G = \left\{ \left\{ R_{i+gj} \right\}_{j=0}^{\min\{R-1-gj, g-1\}} \right\}_{j=0}^{\lfloor R/g \rfloor};$ 
17   for  $G_i \in G$  do
18     upper=M2 if  $l = M1$  else M3;
19     connect'( $R, \text{upper}$ ),  $\forall R \in G_i;$ 
20   end
21 end
22 end

```

Algorithm 1: build5GScenario

It executes clustering to:

- Group AAUs;
- Create the access ring; and
- Create aggregation ring.

R package **mecgen** performs everything underneath inside function **build5GScenario**.

```
1  $H = \text{hierarchical\_clustering}(N);$   
2  $C = \text{cut\_dendrogram}(H, d);$   
3  $R = \cup_{C' \in C} \left\{ \left\{ C'_{i+6j} \right\}_{i=0}^{\min\{C'-1-6j, 5\}} \right\}_{j=0}^{\lfloor C'/6 \rfloor};$   
4 for  $R_j \in R$  do  
5    $M1_n = \min_{M1} \sum_{r \in R_j} \text{Vicenty}(M1, r);$   
6    $\text{connect}(r, M1_n), \forall r \in R_j;$   
7 end
```

```

1  $H = \text{hierarchical\_clustering}(N)$ ;
2  $C = \text{cut\_dendrogram}(H, d)$ ;
3  $R =$ 
   
$$\cup_{C' \in C} \left\{ \left\{ C'_{i+6j} \right\}_{i=0}^{\min\{C'-1-6j, 5\}} \right\}_{j=0}^{\lfloor C'/6 \rfloor};$$

4 for  $R_j \in R$  do
5    $M1_n =$ 
     
$$\min_{M1} \sum_{r \in R_j} \text{Vicenty}(M1, r);$$

6    $\text{connect}(r, M1_n), \forall r \in R_j;$ 
7 end

```



Figure 7: AAUs clustering representation²

¹6 AAUs per cluster, none of them left out

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- 1 $H = \text{hierarchical_clustering}(N);$
- 2 $C = \text{cut_dendrogram}(H, d);$
- 3 $R = \cup_{C' \in C} \left\{ \left\{ C'_{i+6j} \right\}_{i=0}^{\min\{C'-1-6j, 5\}} \right\}_{j=0}^{\lfloor C'/6 \rfloor};$
- 4 $\text{connect}(r_i, r_{i+1 \bmod 6}), \forall r_i \in R_j, \forall R_j \in R;$

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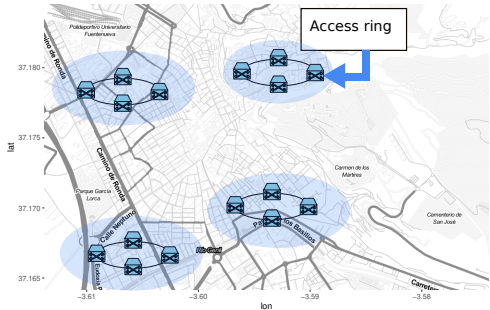


Figure 8: Access rings representation

```

1  $H = \text{hierarchical\_clustering}(N);$ 
2  $C = \text{cut\_dendrogram}(H, d);$ 
3  $R = \cup_{C' \in C} \left\{ \left\{ C'_{i+6j} \right\}_{i=0}^{\min\{C'-1-6j, 5\}} \right\}_{j=0}^{\lfloor C'/6 \rfloor};$ 
4  $\text{connect}(r_i, r_{i+1 \bmod 6}), \forall r_i \in R_j, \forall R_j \in R;$ 
5  $g = 4$  if  $l = \text{M1}$  else  $2;$ 
6  $G = \left\{ \left\{ R_{i+gj} \right\}_{i=0}^{\min\{R-1-gj, g-1\}} \right\}_{j=0}^{\lfloor R/g \rfloor};$ 
7 for  $G_i \in G$  do
8   |    $\text{upper} = \text{M2}$  if  $l = \text{M1}$  else  $\text{M3};$ 
9   |    $\text{connect}'(R, \text{upper}), \forall R \in G_i;$ 
10 end

```

```

1   $H = \text{hierarchical\_clustering}(N);$ 
2   $C = \text{cut\_dendrogram}(H, d);$ 
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7  for  $G_i \in G$  do
8    upper=M2 if  $l = M1$  else M3;
9     $\text{connect}(R, \text{upper}), \forall R \in G_i;$ 
10 end
    
```

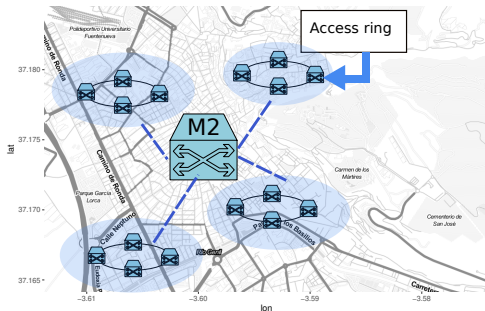


Figure 9: M2 switch handling x4 access rings' traffic

```

1  $H = \text{hierarchical\_clustering}(N);$ 
2  $C = \text{cut\_dendrogram}(H, d);$ 
3  $R = \bigcup_{C' \in C} \left\{ \left\{ C'_{i+6j} \right\}_{i=0}^{\min\{C'-1-6j, 5\}} \right\}_{j=0}^{\lfloor C'/6 \rfloor};$ 
4  $\text{connect}(r_i, r_{i+1 \bmod 6}), \forall r_i \in R_j, \forall R_j \in R;$ 
5  $g = 4$  if  $l = M1$  else  $2;$ 
6  $G = \left\{ \left\{ R_{i+gj} \right\}_{i=0}^{\min\{R-1-gj, g-1\}} \right\}_{j=0}^{\lfloor R/g \rfloor};$ 
7 for  $G_i \in G$  do
8   upper=M2 if  $l = M1$  else M3;
9    $\text{connect}(R, \text{upper}), \forall R \in G_i;$ 
10 end
    
```

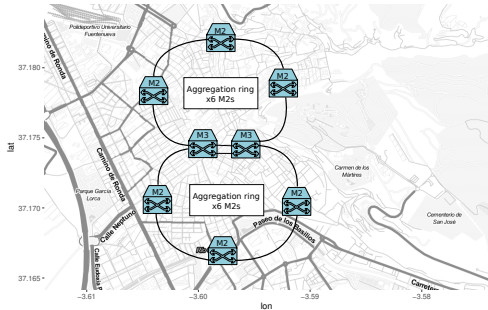


Figure 10: Aggregation rings' representation

Just invoke **build5GScenario** with AAUs' locations

```
1 granadaCells <- read.csv('granada-cells.csv')
2 assocs <- build5GScenario(lats = granadaCells$lat,
3                           lons = granadaCells$lon)
```

assocs contains dataframes with:

- AAUs to M1s;
- M1s to M1s;
- Access rings to M2;
- M2s to M2s; and
- Aggregation rings to M3s.

E.g., add server nodes

```
1 ...  
2 graph <- attachServers(nodes = graph$nodes,  
3                         links = graph$links,  
4                         numServers = 3,  
5                         bandwidth = 12,  
6                         bandwidthUnits = "Mbps",  
7                         distance = 0,  
8                         distanceUnits = "meter",  
9                         switchType = "m2",  
10                        idPrefix = "dell",  
11                        properties = list(cpu=2, mem=20, disk=100))  
12
```

Servers are equally distributed across the switches they are attached to.

Fog nodes generation inside an area

```
1 graph <- attachFogNodes(..., numNodes = 100,  
2                           latB = plazaNuevaLatB,  
3                           latT = plazaNuevaLatT,  
4                           lonL = plazaNuevaLonL,  
5                           lonR = plazaNuevaLonR, ...)
```

Other methods:

- Modify/add graph nodes (e.g., switches or servers) properties:
addNodeProps(); and
- Modify/add graph links (e.g., fiber) properties:
addLinkProps().

mecgen is being used by UC3M netcom research group:

- 5G-CORAL - fog oriented european Project;
- vRoute - FPTAS algorithm³;
- Ongoing research:
 - closed loop 5G orchestration; and
 - mobility orchestration scenarios (ETH, BME + UC3M).

³submitted to INFOCOM2020

VNE algorithms of 5G-CORAL OCS (Orchestration system), on top of volatile fog architecture (generated with **5GEN**)

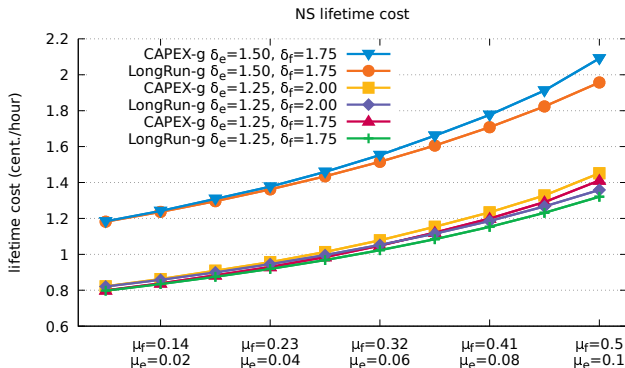


Figure 11: Evaluation on VNE on top of **5GEN** graph

- stores the graph as GML (easy to parse);
- Arbitrarily big graphs;
- SDNlib has small reference abstracted graphs;
- it is based on ITU [3];
- open source: <https://github.com/MartinPJorge/mec-generator/tree/5g-infra-gen>; and
- Given the AAUs it creates the whole infrastructure.





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Repository

[https://github.com/MartinPJorge/mec-generator/tree/
5g-infra-gen](https://github.com/MartinPJorge/mec-generator/tree/5g-infra-gen)

Slides

<https://github.com/MartinPJorge/cscn19>

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