Cost estimation of a fixed network deployment over an urban territory

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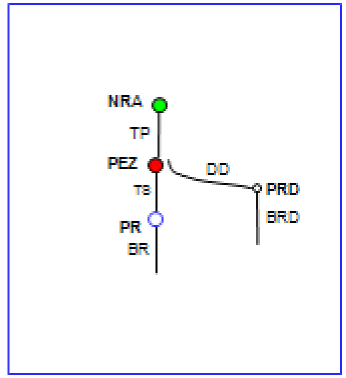
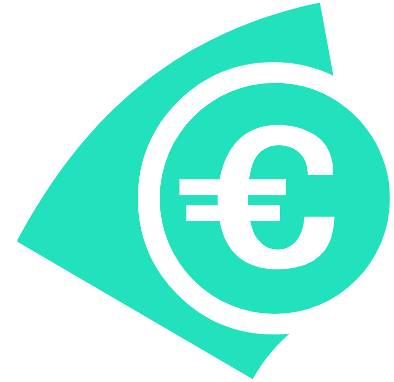
introduction

any city in the world

any hierarchical fixed network



cost estimation



in a user-friendly prototype

- Putting to life stochastic geometry results to solve an operational problem
  - find and format the necessary input data
  - fit the mathematical models to the particular use case
  - extend the results beyond their strictly proven domain of validity
  - obtain realistic results within a few minutes
  - imbed the existing mathematical results in an operational prototype
  - benchmark the results against reality
- No equivalent tool on the market

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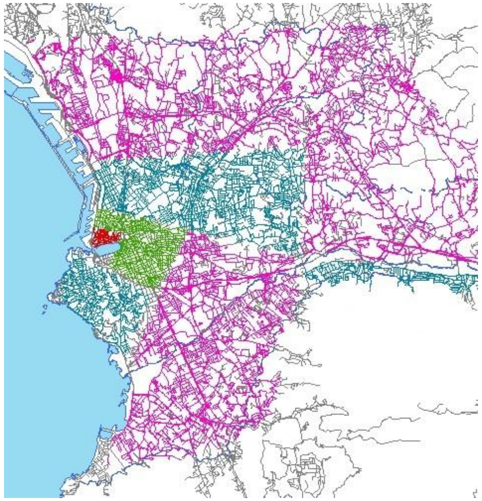
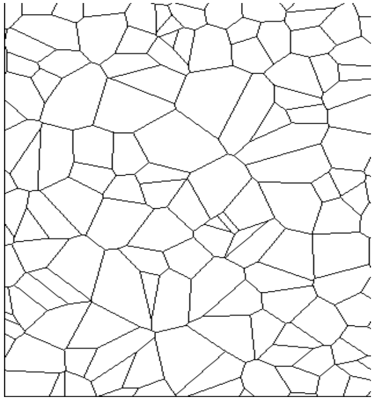
reality



random model



1 realization of PVT Poisson Voronoï Tessellation (ex for blue part)

macroscopic description

part	area km2	type	parameter km-2
red	0.61	PVT	149.04
green	1.65	PVT	114.63
blue	7.98	PVT	38.56
pink	30.87	PVT	18.68
whole city	65.90	PVT	28.08

- the road system supports the network equipment : its morphology is structuring for the network
- only 3 quantities embed the morphology of a planar tessellation :

  number of crossings, number of street segments and length of streets
- the road system is viewed as a realization of a stationary random planar tessellation
  - a whole city map is replaced by very few information (area, model type & parameters)
  - no need for localizing any street segment

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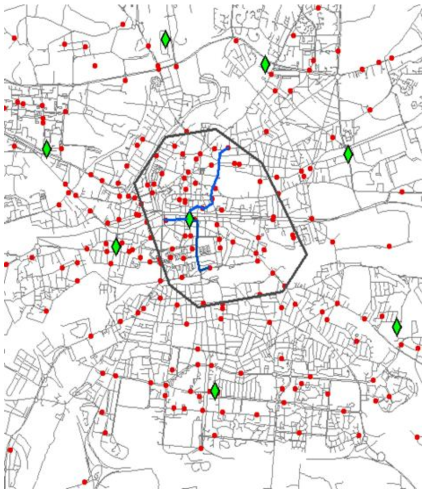
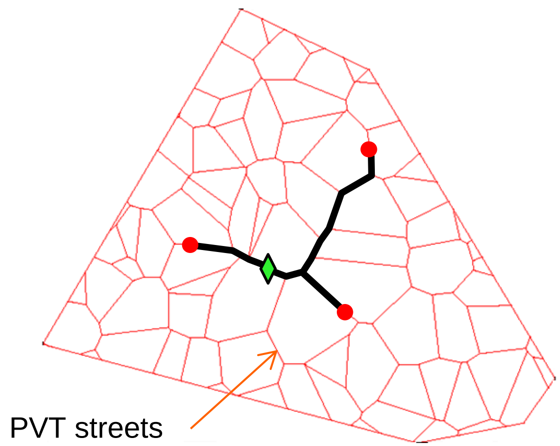
real network

serving zone = Voronoï cell



typical serving zone

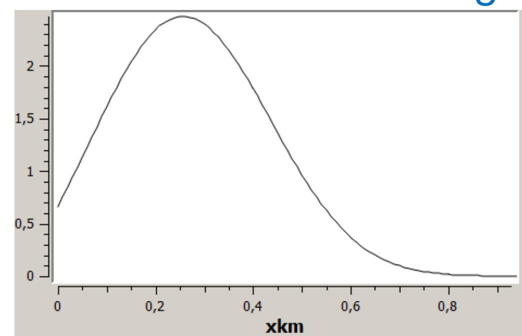
Poisson-Voronoï-Cox-Voronoï cell



macroscopic description

area	type	param.	# node
7.98	PVT	38.56	33

statistics on connexion lengths



- the network is deployed on homogeneous areas (parts or city as a whole)
- the nodes are located on the streets, the links are shortest paths along the streets
- the serving zones of the nodes form a Voronoï tessellation
  - the set of all serving zones is modelled by realisations of a typical serving zone Z
  - the mean area of Z is determined by the number of nodes
- analytical formulas for the probability distribution of the point to point connexion lengths in Z are available
  - this allowed to check that the model fits well reality

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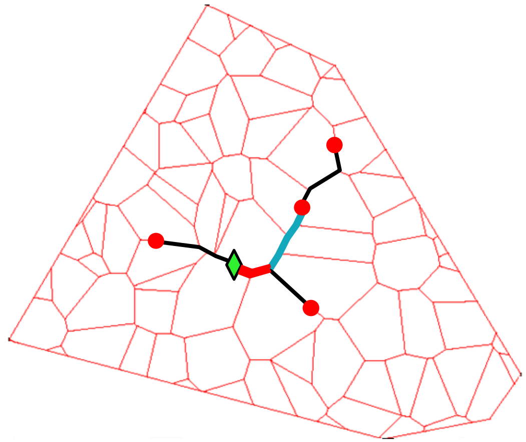
reality

no comment

typical serving zone

random capacity tree

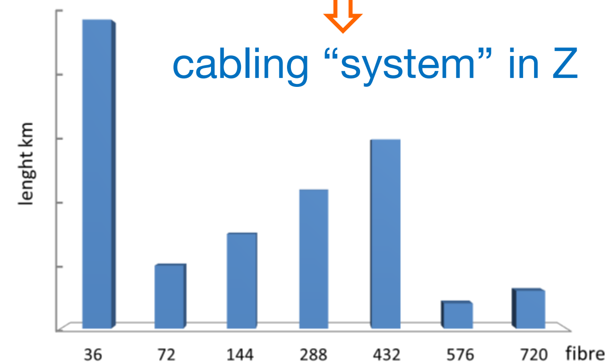


macroscopic description

area	type	param.	# node ◆	# ●	FO / ●
7.98	PVT	38.56	33	321.0	18.5

⇩

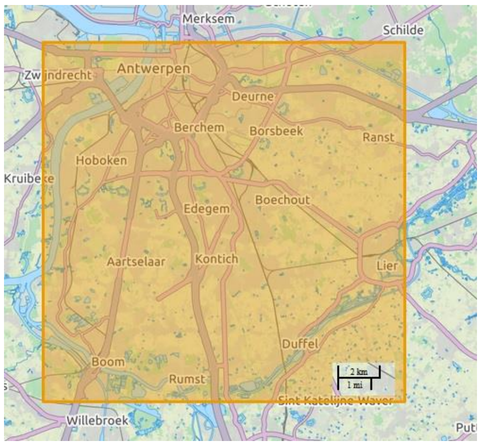
cabling “system” in Z

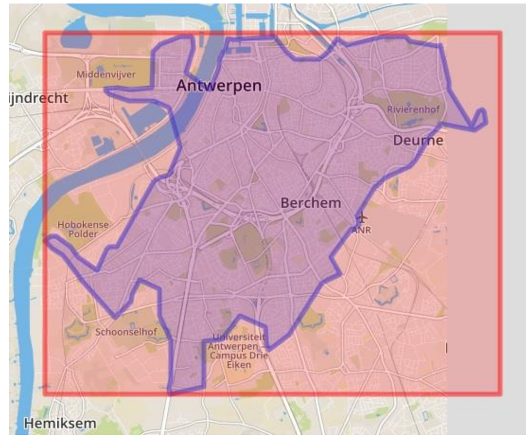


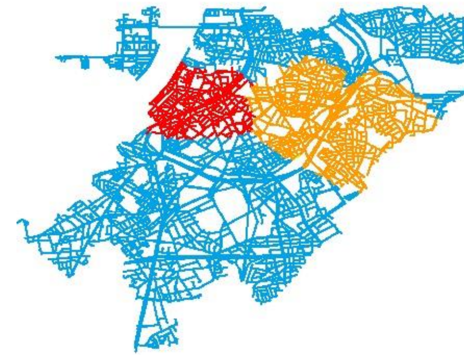
- the typical serving zone is the key ingredient
- an averaged incoming capacity (# fibres) is associated to each ● node
- a street segment is empty or supports one cable of sufficient size
- no closed parametric formula for the random capacity tree
  - limit results for sparse trees /dense trees
  - fast simulations procedures for the cell and the tree
- statistics on type of cable-length are derived from capacity-length computed on realisations on the typical cell and used in the cost function

"OSM Miner" city acquisition 1/3

map from internet	drawing the city's build up area	street system partition
Anvers, Belgique		



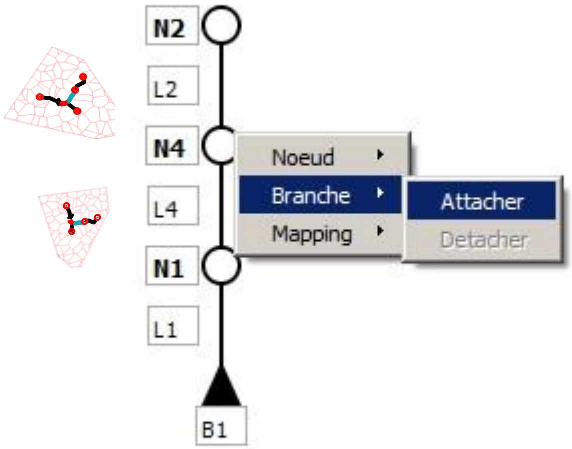


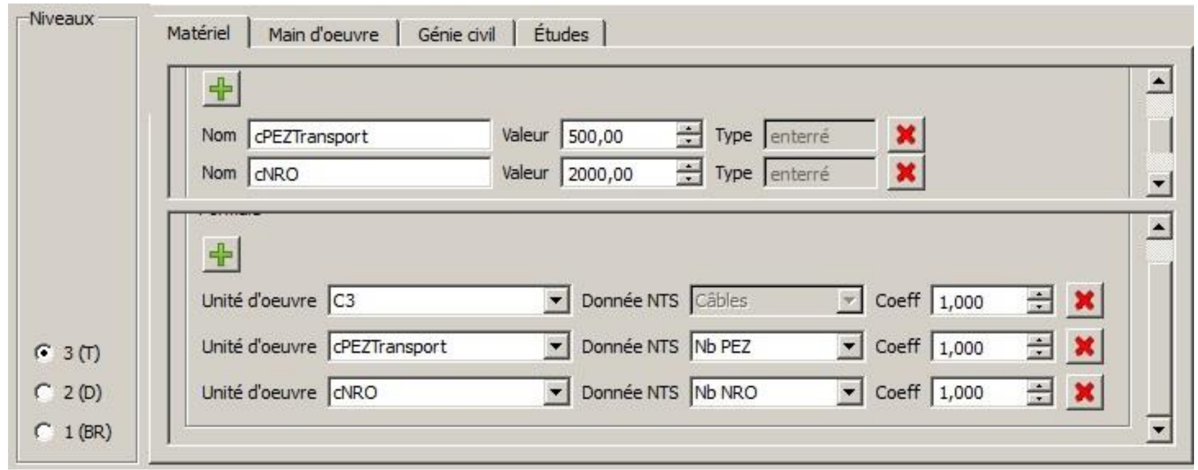


- Open Street Map is a free database for street maps of any city in the world
- detailed data : type of streets, administrative contour
- automatization of treatment
  - detection of build up area contour
  - extraction of streets
  - segmentation in homogeneous parts
  - computation of mathematical model -> « voirie file »

part	area km2	type	parameter km-2
1	3.77	PVT	76.32
2	9.32	PVT	60.04
3	40.41	PVT	42.27
whole city	53.50	PVT	47.73

"Network Topology Synthesis" Tool 2/3

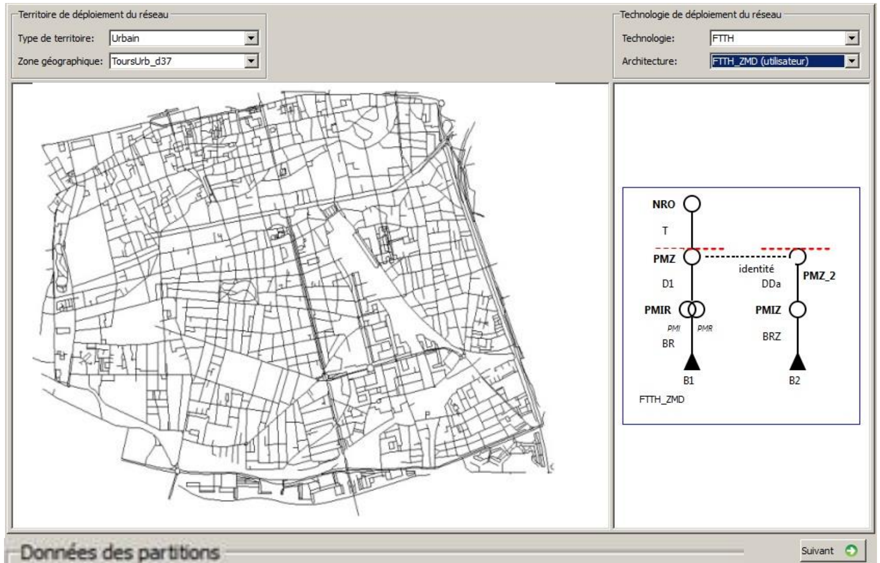




- network design : immediately usable in the prototype
  - architecture : hierarchical network
  - engineering: relates nodes to population and technology
- generic specification of cost function
  - declined in material, manpower, civil work and studies on each network level
  - specification of unit costs for all equipment
  - specification of rules to compute the global cost
- compute the main values (covered road system, cable laying…) by simulation on the typical cell

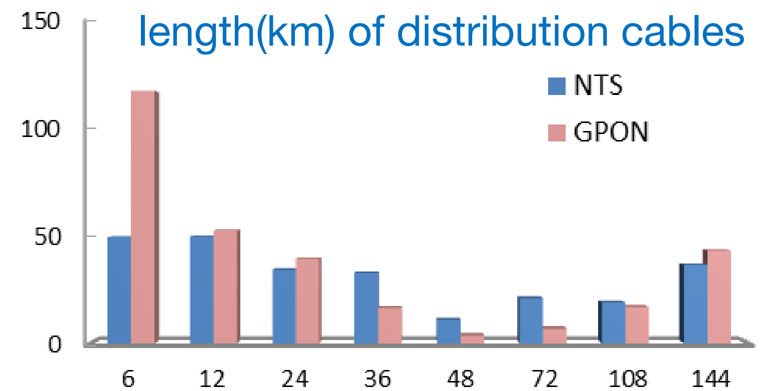
prototype

benchmark on Tours 3/3



Données des partitions

Part	Zone	Type	Int.	Crois.	Segmt.	Quartiers	Longueur
tot	9.2	PVT	100.7	1857.2	2785.8	928.6	185.1



cost

1-NTS/GPON	cables	Total
Transport	2%	8%
Distribution	8%	7%
Total cost	6%	4%

- GPON optimizer (operational tool in Orange) optimization of global deployment cost
  - on the architecture required by the French regulator Arcep and engineering constraints
  - ☺ optimal location of nodes & cabling scheme, exact path of fibres, detailed cost function
  - ☹ computational time (tens of hours) ⇨ restricted to small areas
- NTStool designed for macroscopic estimation in very large areas
  - available data set Tours (9 km2) is the limit range
  - ☺ structuring cost units can be addressed
  - ☺ computation in minutes
- detailed comparison : cabling system ok, cost within %

Conclusion

- the prototype offers an optimization for a decision problem with M€ yearly OPEX costs stakes and anticipates industrialization

- stochastic geometry is used to address a very practical use case :
  - some work needed to create a usable tool
  - not obvious that costs could be obtained (simulation time remains reasonable)
  - no equivalent tool on the market

- difficult to explain that a handful of parameters can produce reliable statistics in no time on a very large territory
  - very weird approach for operators, used to databases

- a lot of other mathematical results can still be put to use
  - other road models
  - for rural territory or at a full country scale
  - to address other use cases

- we are at your disposal for prototype demonstration

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thank you for your attention

references

Maier R. & Schmidt S. (2003). Stationary Iterated Tessellations. Adv Appl Prob (SGSA) 35:337-353

Courtat T. (2012). Promenade dans les cartes de villes. Phénoménologie mathématique et physique de la ville : une approche mathématique – PhD Thesis, Paris Diderot

Gloaguen C. , Fleischer F., Schmidt H., Schmidt V. (2006). Fitting of stochastic telecommunication network models via distance measures and Monte-Carlo tests. Telecommun Syst 31(4):353-377.

Fleischer F., Gloaguen C., Schmidt V., Voss F. (2009). Simulation of the typical Poisson-Voronoï-Cox-Voronoïcell. Journal of Statistical Computation and Simulation 79(7):939-957.

Gloaguen C., Voss F., Schmidt V. (2011). Parametric Distributions of Connection Lengths for the Efficient Analysis of Fixed Access Networks. Ann Telecommun 66:103-118.

Neuhäuser D., Hirsch C., Gloaguen C., Schmidt V. (2015). Joint distributions for total lengths of shortest paths trees in telecommunication networks. Ann Telecommun 70:221-232.

Neuhäuser D., Hirsch C., Gloaguen C., Schmidt V. (2015). Parametric modelling of Sparse Random Trees Using 3D Copulas. Stochastic Models 31(2):226-260.

OpenStreetMap. http://openstreetmap.org. Accessed November 28th, 2016.