TSUT:
The **S**till **U**nnamed **T**ool
for wireless link planning and mesh network topology generation

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whois Leonardo

- Professor at the University of Venice
- Up to May, researcher at the University of Trento (Italy)
- I was the WP technical coordinator of the netCommons project, a three-year H2020 research project on Community Networks that ended in March 2019, led by University of Trento
- also a member of the ninux.org community network in Florence

The netCommons Project: 2016-2019

- H2020 Financed project (CAPS)
- 2016-2019
- 4 Universities
- 1 Research Center
- 1 not-for-profit association
- 6 countries

`www.netcommons.eu`

TSUT: The Still Unnamed Tool

- TSUT was not initially part of the project, it came out as an idea in the process
- It has a double nature:
  - For Communities: tool and methodology to plan your network
  - Research: generate and study realistic network topologies of a mesh network
- Three components:
  1. Open data surface models
  2. Pathloss models derived by data-sheets and some literature
  3. An engine that simulates the growth of the network

Warning

Current state:

- Python code on github[a], but really to be revised (realized in a rush for a deadline. . .)
- Quite complex, there are a lot of different components (postgres/postgis, networkx), partial test coverage
- A lot of heuristics in our model, which we will hopefully improve in the future
- Consider this as a Proof of Work
- Happy to receive any feedback

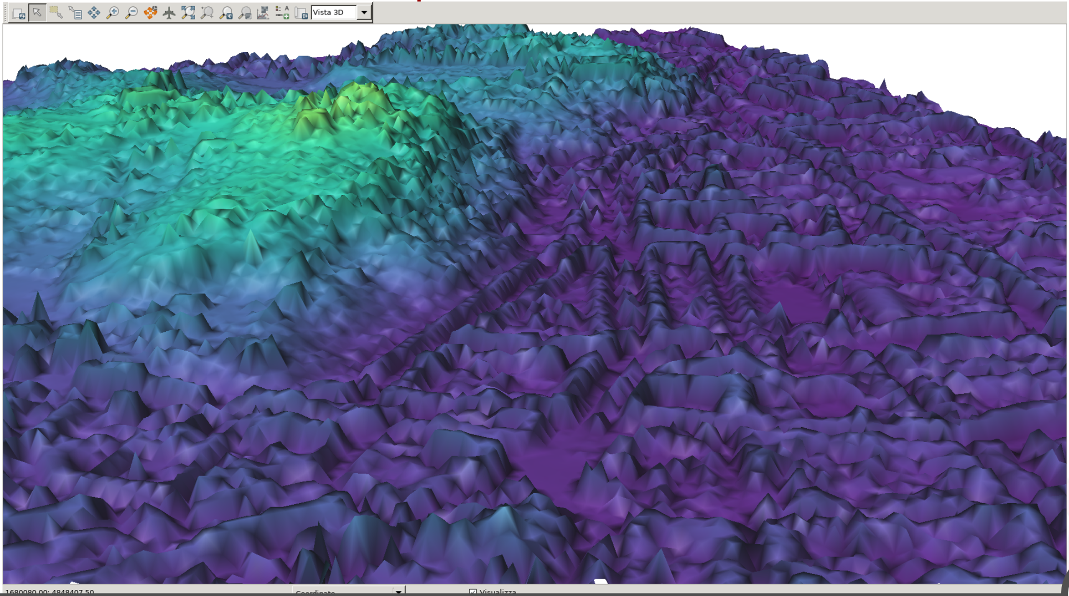
[a] https://github.com/AdvancedNetworkingSystems/TerrainAnalysis

Dataset

- We start from the open data-set of the building altitudes of an area (Lidar data)
- We add the building shapes taken from OpenStreetmap/Catasto
- For each couple of buildings, we can compute:
  - If there is Line of Sight
  - If the Fresnel zone is partially obstructed
  - How high is the path loss considering the Fresnel occupation

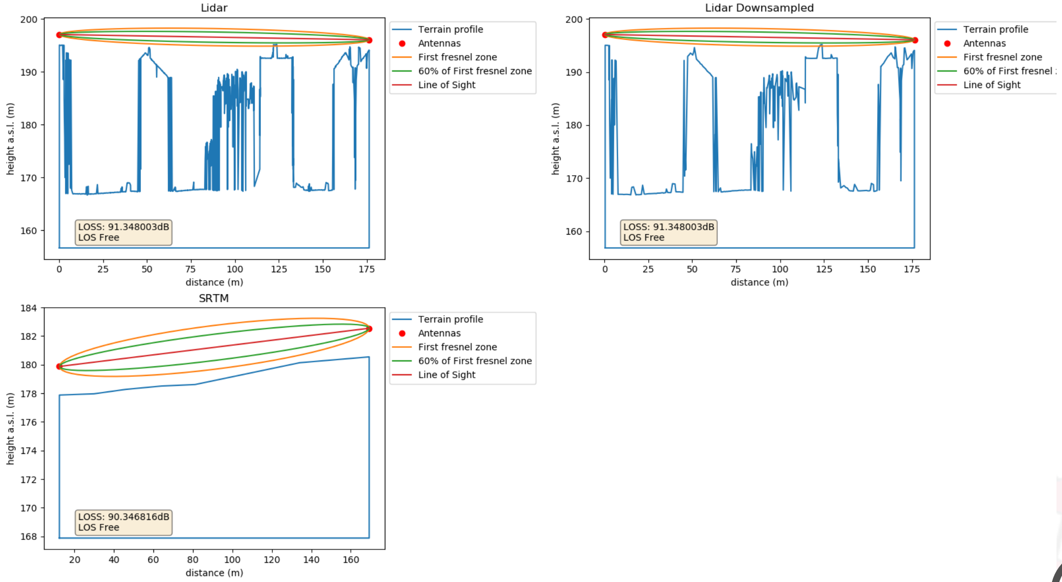
A CN simulator: Lidar data

A CN simulator: altitude profiles



A CN simulator: Lidar + OS

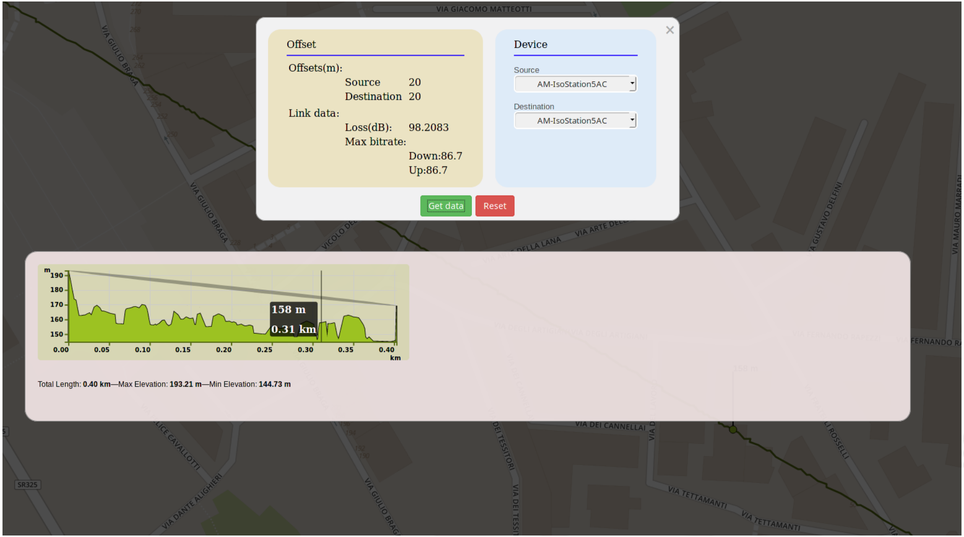
A CN simulator: Fresnel zone with Different Sampling



A Database of Devices

- We collected the data-sheets of Ubiquiti devices (July 2018)
- Given the path loss, we can choose the most appropriate device according to some criteria (highest bit-rate, lowest cost, narrow antenna aperture. . .)
- We assume Point-to-point links, and can estimate the economic cost (€) of each link/node

A very simple web interface (still not public)



From Links to Networks: Growth Models

Now that we can estimate the link performance, we try to model the network growth:

- We decide the location of a network gateway, and we pick a sequence of random buildings in the area
- For each node, we try to connect it to some existing one
- We estimate the maximum available bandwidth per node in saturation conditions: the “guaranteed bandwidth per user”
- This involves a number of heuristics to model the routing decision, channel allocation, bandwidth/txpower negotiation...

Stop Condition

At some point the network growth must stop:

- Since we have a way to estimate the guaranteed bandwidth per node, we use a derived global metric: the percentage x of nodes that have at least B_{min} Mb/s
- The stop condition is: stop growing when adding a new node will push x below 95%

What research we do with TSUT

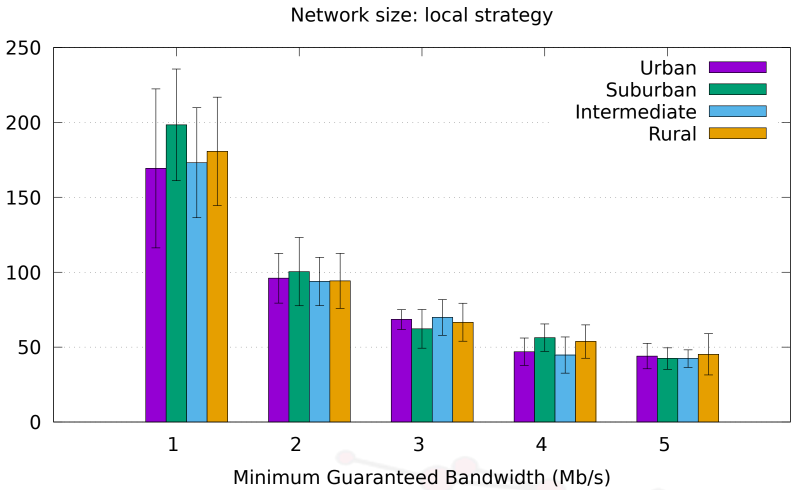
Research questions

- How much can the network scale?
- Can we improve its scalability with local-only decisions (no global planning)?

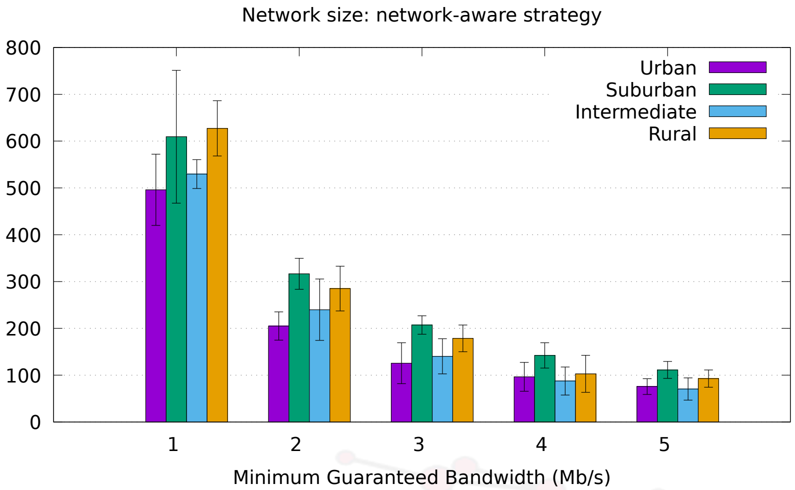
Attachment Algorithm

- Given a new potential node that can connect to a number of existing nodes, what is the best one?
  - Greedy: The one that gives you the best link bandwidth
  - Network-aware: The one that gives you the best metric, (practically, it better distributes the load on the gateway)

Network Growth: Average Size, Greedy approach (10 runs)



Network Growth: Average Size, Network-aware approach (10 r)



Conclusions

- We realized a tool that can be used to model the growth of a network
- The methodology can be replicated using data from any place
- Communities can use it to assess the feasibility of a link
- We many ideas to keep developing this tool in several directions (off-line discussion if you are interested, no space left. . .)

Thank you, questions?

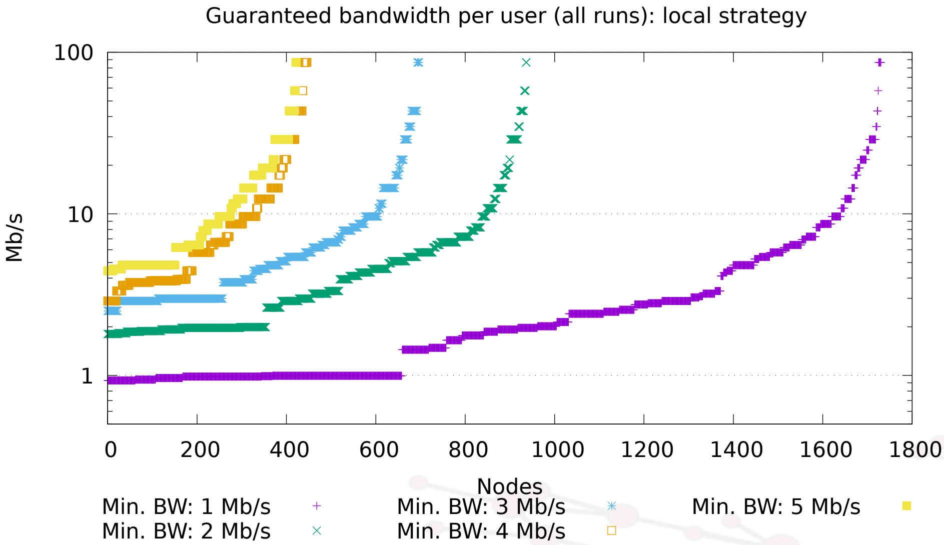
Credits

- Code by myself, Gabriele Gemmi and Daniele Mazzetti (the web interface)
- Concepts and more results published in *“Towards Scalable Community Networks Topologies”*, L. Maccari, G. Gemmi, R. Lo Cigno, M. Karaliopoulos, L. Navarro. Available as early access on Ad Hoc networks journal
- Co-Funded by the Horizon 2020 programme of the European Union, Grant Number 688768

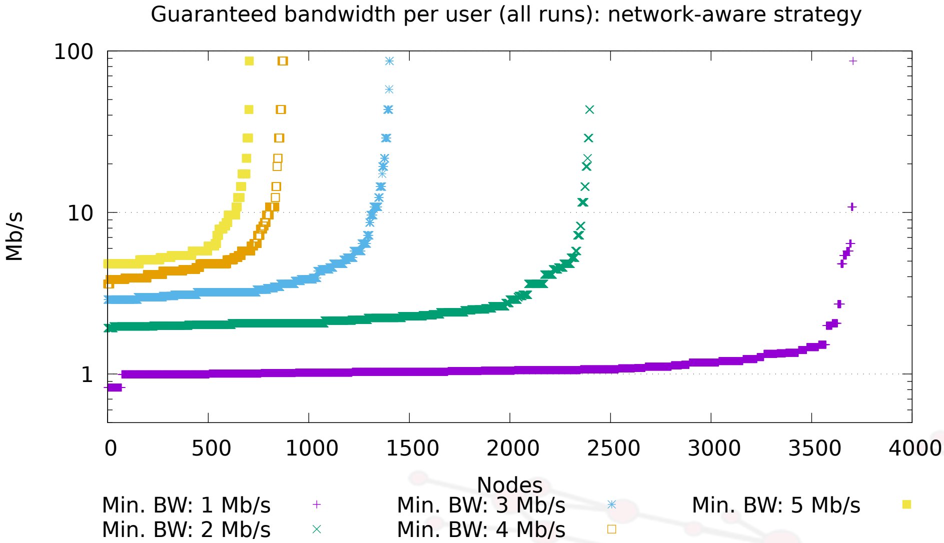
Examples of network evolution

Topology Examples: map, animation.

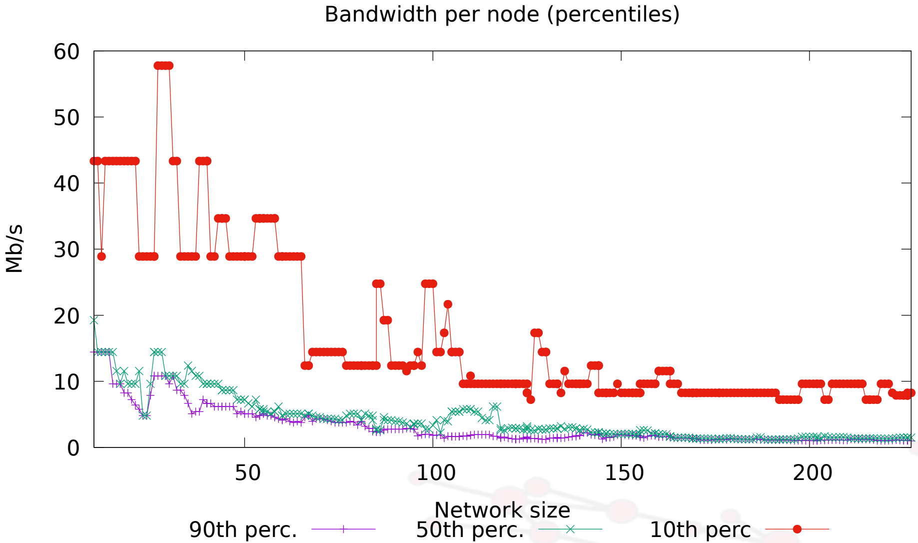
Bandwidth distribution (10 runs)



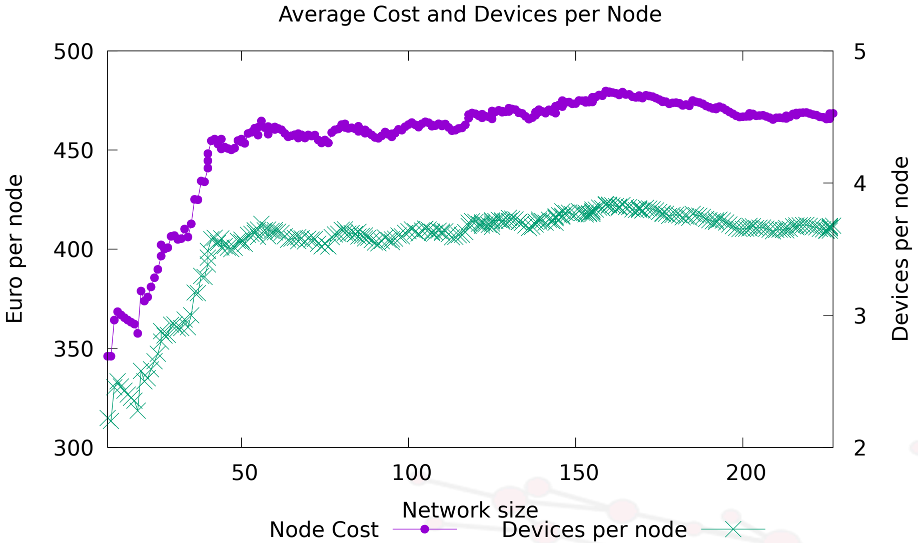
Bandwidth distribution: network-aware attachment



Growth of one network: Bandwidth



Growth of one network: Price



More things to do with TSUT: Networks Domain

1. Not only CAPEX, but estimate OPEX too
2. Different technologies: TVWS, 5G, IoT...
   - Ex.: 5G needs an extreme densification of the BS, uses mm wavelength, can we estimate coverage and cost?
   - Nokia proposed to use mesh networks backhaul[1].
   - How feasible is it? How much people we can reach with a mesh backhaul for 5G?

[1]Chen et. al. "*5G Self-Optimizing Wireless Mesh Backhaul A Proof-of-Concept Demo on Mesh Interconnected Small Cell Wireless Backhaul*" INFOCOM '15

Cost sharing: two layers network

- So far we assumed every node owner pays the same: is it the correct way?
  - Pros: equal
  - Cons: if you can't afford it, your're out; probably unfair
- Reality suggest alternatives. In the Sarantaporo.gr community network, they use a different mode:
  - Two kinds of node: supernodes and leaf nodes
  - Supernode owners pays for their infrastructure, leaf nodes for network access
  - Leaf nodes pay fees to the supernode owners
- In a project deliverable (D2.8) we elaborated possible cost sharing strategies.
- We are currently implementing this strategy in the simulator.

What more: Interdisciplinary Research Domain

1. Include more open data from national surveys: current Internet coverage, average income, age, education. . .
2. $\rightarrow$ try to forecast **who** is going to be served by this technology: is it going to serve only the already connected ones (young, educated, middle-to-high income)?

Need: Improve Nodes Generation

- So far, we pick new nodes at random.
- What if we use more open data to choose locations that are more or less feasible?
- National surveys publish huge open data sets with demographics: income, age, education
- These data sets are published down to the "block" detail
- Can we estimate the possible demand of connectivity based on those parameters?
- Can we compare the effectiveness of our cost sharing models with realistic demand constraints?
- Can we tune them based on the area (urban/suburban...)

Societal Impact

- If our mesh networks do not evolve only depending on geographic/terrain/technological constraints, who do they reach?
- Do they produce more or less inequality? Do they connect the already connected one?
- What about the other societal impact?

Societal Impact

- How do mesh networks (or any other network we can model) compare, in terms of societal inclusion?
- The fact that we pose some technological constraints, introduces an intrinsic bias towards some social groups?
- Can we compare different technologies?

Cost sharing: introduce CNO

- In some cases, local heuristics are not enough
- One node needs more capacity to let other nodes connect, but the owner has no incentives to upgrade the hardware
- We could introduce a Community Network Owner, a collective body that suggests network improvements with a global view on the network evolution.
- CNO can collect money from node owners and invest some to "refactor" pieces of network
- Question: who should contribute to the CNO? how much?
- Potential Answer: central nodes are important for the network, should pay less. Peripheral nodes are freeriders, should pay more.
- **Main issue**: To test strategies, we need a demand model...

One last bit: Governance

- A distributed network grows “organically” and in an unplanned way
- It replaces a proper planning with redundancy obtained with network density
- The more it maintains its flat, unplanned organization, the more agile it remains, the easier it is to govern
- With lightweight nudging and consensus these networks grow up to hundreds of nodes