TSUT: The Still Unnamed Tool 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

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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

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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)
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...
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 $B_{\text{min}}$ 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)

Minimum Guaranteed Bandwidth (Mb/s)

Network size: local strategy

Urban
Suburban
Intermediate
Rural

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Network size: network-aware strategy

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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...)

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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)

Guaranteed bandwidth per user (all runs): local strategy

Min. BW: 1 Mb/s
Min. BW: 2 Mb/s
Min. BW: 3 Mb/s
Min. BW: 4 Mb/s
Min. BW: 5 Mb/s

Note: $B_m$ is unevenly distributed

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Bandwidth distribution: network-aware attachment

Guaranteed bandwidth per user (all runs): network-aware strategy

Min. BW: 1 Mb/s
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Growth of one network: Bandwidth

Bandwidth per node (percentiles)

90th perc.  50th perc.  10th perc

Network size
Growth of one network: Price

Average Cost and Devices per Node

Euro per node

Devices per node

Node Cost

Network size

Devices per node
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?

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\(^1\)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, you’re out; probably unfair

- Reality suggests alternatives. In the Sarantaporo.gr community network, they use a different mode:
  - Two kinds of node: supernodes and leaf nodes
  - Supernode owners pay 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