TSUT: The Still Unnamed Tool for mesh network planning

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Till May I was a researcher at the university of Trento (Italy).
I am a member of the ninux.org network in Florence.
I was the WP technical coordinator of the netCommons project, a three-year H2020 research project on CNs that ended in March 2019.
The netCommons Project: 2016-2019

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

- Under a global point of view:
  - we influenced the EU legislation mechanism to be more CN-friendly
  - we convinced UNESCO to include CNs in the way they evaluate national ICT policies

- Under a local point of view:
  - We described how several CNs work, their sustainability and governance
  - We contributed to the development of some
  - We analysed the technical evolution of some
  - We also contributed with open source code, guides etc.
  - ...

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:
  - Research: generate and study realistic network topologies of a mesh network.
  - Communities: help to plan your network
- Three components:
  1. Open data surface models
  2. Radio models taken from 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

\(^a\)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 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 cost of each link/node
A very simple web interface
A very simple web interface

click me in case you don’t remember the URL
Growth Heuristics

- We decide the location of a network gateway, and we pick a sequence of random buildings in the area.
- We connect each new node to some existing one.
- We need to model 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...
Once we can estimate the minimum bandwidth to the gateway per node, we need a stop condition.

The stop condition is: stop growing when $x\%$ of the nodes have less than $B_{\text{min}}$ Mb/s guaranteed.
What research we do with TSUT

- Simulate how much such a network can scale
- Given a new node, suggest a reasonable attachment algorithm: what is the best neighbour to connect a new node?
  - Greedy: The one that gives you the best link bandwidth
  - Network-aware: The one that better distributes the load on the gateway
- Examples: map, animation.
Growth of one network: Average Size (10 runs), Greedy approach
Network Size: network-aware attachment

Minimum Guaranteed Bandwidth

Network size

Urban
Suburban
Intermediate
Rural
Thank you for your attention
Questions?

Credits
- Code by myself, Gabriele Gemmi and Daniele Mazzetti (the web interface)
- Ideas and discussions by the researchers from netCommons (paper under review right now...)
- Co-Funded by the Horizon 2020 programme of the European Union, Grant Number 688768
Bandwidth distribution (10 runs)

Guaranteed bandwidth per user (all runs): local strategy

Note:

Min. BW is unevenly distributed

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Bandwidth distribution: network-aware attachment

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

Nodes

Mb/s

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

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Growth of one network: Bandwidth

Bandwidth per node (percentiles)

 Mb/s

Network size

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Growth of one network: Price

Average Cost and Devices per Node

Euro per node

Devices per node

Network size

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TSUT
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
What more: Interdisciplinary Research Domain

1. Study economic incentives: what is the best strategy to share the cost?
2. Include more open data from national surveys: current Internet coverage, average income, age, education... → 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)?
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.
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…
Warning!

What follows is a mix of half-baked ideas and some handwaving!
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?
The Digital Divide

Percentage of Households by Broadband Internet Subscription, Computer Type, Race and Hispanic Origin

- **Desktop or laptop, and handheld has broadband subscription**
  - White alone, non-Hispanic: 64.5%
  - Black alone, non-Hispanic: 49.3%
  - Asian alone, non-Hispanic: 50.1%
  - Hispanic (of any race): 55.0%

- **No desktop or laptop, has handheld or other computer, has broadband subscription**
  - White alone, non-Hispanic: 11.1%
  - Black alone, non-Hispanic: 7.2%
  - Asian alone, non-Hispanic: 5.0%
  - Hispanic (of any race): 6.1%

- **No broadband or no computer**
  - White alone, non-Hispanic: 21.2%
  - Black alone, non-Hispanic: 36.4%
  - Asian alone, non-Hispanic: 11.0%
  - Hispanic (of any race): 10.1%

1. Broadband Internet refers to households who said "Yes" to one or more of the following types of subscriptions: DSL, cable, fiber optic, mobile broadband, satellite, or wired wireless.

Note: Estimates may not sum to 100 percent due to rounding.

Source: 2015 American Community Survey
www.census.gov/programs-surveys/acs/
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?
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.