# Topology Control and Manipulation in a Large Scale Wireless Network Testbed

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## I. Introduction

While analytical models and well-considered network simulations are invaluable for wireless network researchers, they cannot capture the full complexity and dynamics of the error prone wireless medium. The simplified assumptions that are necessarily used in simulations and calculations often cause unwanted side effects, causing protocols to fail or perform considerably worse than expected under real-life conditions.

Consequently, the international research community is increasingly recognizing the added value of experimental wireless network deployments. Recently, the w-iLab.t testbed was installed at the three floors of the buildings of the IBCN research group and at the offices of the IBBT research institute in Ghent, Belgium. With nearly 200 wireless WiFi nodes, it is one of the largest wireless testbeds of its kind installed in a real office environment worldwide. As the output power of the wireless interfaces cannot be set to an arbitrarily low value, and the area of the test site is limited, all nodes are within each other's transmission range by default. Therefore, several techniques to manipulate the topology in testbeds are briefly discussed in this paper. It is also shown how by combining techniques, the topology of the w-iLab.t can be manipulated in order to recreate both very sparse and very dense networks.

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## II. Parameter space

Figure 1 shows an overview of the third floor of the w-iLab.t testbed at the IBCN buildings. Each dot in the figure, represents a node in the testbed.

Several parameters have an influence on the topology of the WiFi testbed:

- **Manual node selection.** A developer can choose to activate only a subset of the nodes, influencing the density of the network.
- **MAC address filtering.** WiFi frames include a sender MAC address. A specific topology can be forced by embedding MAC filters in the protocols, discarding certain packets at the MAC layer before they can be processed by upper layer networking protocols such as the routing protocol. The major drawback of this technique is that, while packets are no longer seen by higher layer protocols, they still cause the node to spend resources to the lost packets, and still cause radio interference.
- **Transmission rate.** WiFi devices, based on the IEEE802.11 standard, support different transmission rates. For example, WiFi devices following the IEEE802.11g standard allow physical data rates from 1 Mbit/s up to 54 Mbit/s. In order to receive packets at higher data rates, the received signal strength should be higher. Thus, selecting a higher transmission rate limits the possible number of wireless links in the network. The technique can obviously not be used when designing rate control algorithms.
- **Transmission power.** A lower transmission power at sender side results in a lower received signal strength at the the receiver. Lowering the

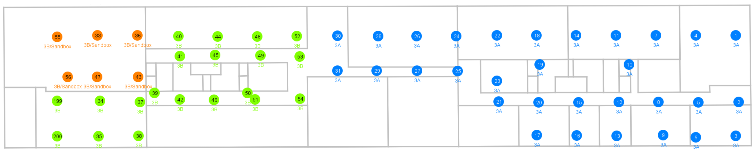

Figure 1. Third floor of the w-iLab.t testbed at the IBCN buildings. Floor area is approximately 90m x 18m.

transmission power reduces the possible number of wireless links.

- **Physical signal attenuation.** In case none of the above techniques can be used or the resulting topology of the testbed is still too dense, external attenuators can be added between the radio interface connector and the antenna.

## III. Combining techniques

Physical signal attenuation is the only way to reduce the number of links in the network without reducing the number of nodes in the network (node selection), that does not require support from any protocol or driver on the test nodes. Unfortunately, as attenuators need to be physically installed at the nodes, attenuation cannot easily switched on and off.

In the w-iLab.t testbed, this issue can be overcome by combining physical attenuation with the transmission power setting of the cards. In order to determine an optimal value for external attenuator, the testbed hardware was first benchmarked in order to discover the required SNR at the receiving interface for each data rate. These measurements showed the required SNR for transmission at 54Mbit/s and 1Mbit/s to be respectively be 20dB and 2dB. By measuring the signal level of received packets when a single node is transmitting in the network, the path losses in the office environment were measured. These measurements show that by adding an attenuator of 15dB on the sending and receiving antenna of the interfaces, only the closest neighbors of a node transmitting at it lowest power setting (0dBm) can be reached at the highest data rate, while most other nodes cannot longer be detected at all. This is an ideal situation for real life experiments in sparse networks.

However, when the transmission power of a transmitting node is set at its maximum value of 20dBm, measurements show that half of the nodes on a floor can be reached from a node located at the sides of the building, of which 20% still at the highest data rate. This results in a dense wireless network. Thus, by combining external attenuation with power settings of the interface cards, large variations in topologies can be obtained.

## IV. Conclusions

A large scale wireless testbed is an important tool for protocol developers while designing and evaluating wireless architectures and protocols. Such testbed was recently installed at the IBCN/IBBT offices. Different ways to manipulate the topology of the testbed were briefly discussed, and it was shown how attenuator values can be determined. For the example of the third floor of the w-iLab.t testbed, it was shown that combining the output power settings of the wireless interface card with an attenuator of 15dB on every radio interface allows the number of neighbors of a typical node in the testbed to vary between only the nearest neighbors and half to all of the nodes on the floor, depending on the node's location. Thus, combining physical attenuation through external attenuators with the output power setting of the wireless interfaces, is a powerful and controllable strategy to manipulate the topology in a large scale wireless testbed within the limited area of an office building.

## Acknowledgments

Stefan Bouckaert thanks the Institute for the Promotion of Innovation through Science and Technology in Flanders (IWT Vlaanderen) for funding this research through a grant.