Master's thesis

Towards Ultra-reliable Wi-Fi: Adaptive Redundancy for Mixed-criticality Traffic via Wi-Fi 7 Multi-link Operation (MLO)

Abstract

New Wi-Fi 7 multi-link operation (MLO) ambitiously aims to render wireless communication more efficient and reliable. High-efficiency (HE) wireless stations (STAs) can now utilize all 2.4, 5, and 6 GHz frequency bands over multiple radio interfaces simultaneously to avoid channel congestion and interference, and eventually provide lower latency and increased throughput. Beyond the existing reliability mechanisms in Wi-Fi, this also enables transmitting high-priority traffic over multiple links redundantly to guarantee their timely delivery even in challenging scenarios. However, sending duplicate frames for reliability increases the energy consumption of STAs and channel contention for other STAs with low-priority traffic. Accordingly, the main goal of this thesis is to develop adaptive redundancy procedures that ensure the reliability of high-criticality traffic with minimal additional congestion and energy consumption. This includes selecting the *best* links for redundant communication and dynamically switching on/off redundancy depending on the channel conditions and traffic characteristics.

Objectives

In the context of the thesis, you are going to:

- implement MLO in OMNeT++, which is a C++-based network simulator, by extending the existing modules of 802.11 standard in the simulator.
- define fault tolerance (redundancy) profiles, e.g., which traffic should be sent redundantly and when, for mixed-criticality traffic.
- develop adaptive redundancy procedures on Wi-Fi MLO w.r.t. the defined profiles and varying channel conditions.
- evaluate the trade-offs between redundancy and energy consumption.

Requirements

It is a big plus to be experienced in (or strongly motivated to learn) the following:

- Fundamentals of wireless communication, particularly Wi-Fi.
- Understanding of reliability concepts, e.g., fault tolerance, redundancy etc.
- Programming skills in C++
- Network simulators, i.e., OMNeT++

Literature

- E. Khorov, I. Levitsky and I. F. Akyildiz, "Current Status and Directions of IEEE 802.11be, the Future Wi-Fi 7," in IEEE Access, vol. 8, pp. 88664-88688, 2020, doi: 10.1109/ACCESS.2020.2993448.
- M.T. Suer, C. Thein, H. Tchouankem and L. Wolf, "Multi-Connectivity as an Enabler for Reliable Low Latency Communications—An Overview," in IEEE Communications Surveys & Tutorials, vol. 22, no. 1, pp. 156-169, Firstquarter 2020, doi: 10.1109/COMST.2019.2949750.
- D. Cavalcanti, C. Cordeiro, M. Smith and A. Regev, "WiFi TSN: Enabling Deterministic Wireless Connectivity over 802.11," in IEEE Communications Standards Magazine, vol. 6, no. 4, pp. 22-29, December 2022, doi: 10.1109/MCOM-STD.0002.2200039.

Thesis Checkpoints

Title
Initial Assessment
Beta Version of Proposal (only between student and supervisor)
Initial presentation (after a few weeks of initial reading, literature study, and tooling)
Written Proposal (Proposal can be submitted only if both fields below are marked with Yes by direct supervisor and referee)
Can register Thesis (including finalized title)?

Title
(opt. Intermediate presentation -- useful to get quality feedback for the direction of the thesis, good idea to do it when starting the e
Beta Version of Thesis (1 time chance of feedback from referee)
Code review
Written thesis
Final presentation (comprehensive overview, selected results)

Notes

Lab Rules

As the lab is shared among all of us we ask you to follow one simple rule. Failing that, we will restrict access to the lab and our resources.

   0. Make sure that your working in/with the lab does not negatively impact other people's work

To give some examples:

   1. Do not change the hardware configuration or unplug any cables.
      Feel free to connect your Laptop to a monitor if there is an unconnected VGA cable on the desk.
      However you must not disconnect any peripherals of any Lab computer in the room.
      When leaving make sure you select the right input mode of the monitor such that it again shows the screen of the Lab computer.
   2. Do not execute code you did not write.
      This not only extends to binaries downloaded from the Internet, but also source code, scripts, command lines, etc. We will be happy to supply you with any software you might need. Please ask your supervisor.

   3. Do not execute the sudo or su command.

   4. Do not shut down or reboot computers.
      If a computer crashed please inform our administrators.

   5. Do not monopolize resources.
      A good rule of thumb is to not use more than max. 6 CPU cores and max. 8 GB memory p machine, so fellow users can still log in.

   6. Do not print more than you need.
      If you print something, be sure to pick it up from the printer.

   7. Do not take hardware out of the lab without permission.
      If you need to take hardware home, please check this equipment out with HaJo Kraus.

   8. Do not leave the lab (nor your machine) unlocked when you leave.
      We are not responsible for any theft.

   9. Do not litter.
      Clean up after yourself.

Thank you!

Paderborn, 22 May 2018

* Please be aware of the following
when working in the CCS lab. * Regularly check your thesis wiki page, and read both the new_students_infopage and

wiki pages. * After a settling-in period of 2 months (Bachelor thesis) or 3 months (Master thesis), the student and their supervisor(s) can agree on working together on the topic. This agreement is formalized when the thesis proposal is accepted by the supervisor. However, both parties reserve the right to withdraw from further cooperation before the final submission of the proposal. Once the proposal is accepted by the supervisor, it has to be registered with the examination office, otherwise the thesis will be canceled. * Submission is possible before the official deadline of the examination office, but not before 50% of the official time. * https://www.tu.berlin/en/studying/organizing-your-studies/study-and-examination-regulations/

Log

We assume there will be a meeting between you and your supervisor at least every two weeks. In the meantime, please indicate your progress by email. If there is no log entry for more than one month, we have to assume the thesis is to be canceled.

- YYYY-MM-DD: <what happened in the last week(s), outcome of discussions within the meetings, plans for the next week, deliverables...>

End-of-thesis Checkpoints

Once you are finished with your thesis, collect all of your simulation output files (.sca, .vec) in `scratch-shared/` and remove all of the output files which are not used in the final written thesis. Create a `README.txt` documenting the points below.

task
Add thesis to our BibDB
Final git commit (hash) for the developed simulation code/model. Create a branch called `thesis-final`
Final git commit (hash) for the scripts used to parse the raw data to obtain the csvs; include the command for starting the scripts; Cr
Directory location and structure of the result files and parsed files (if applicable)
Final SVN commit for the written thesis, the final presentation
Final git commit (hash) for the scripts used for plotting in the final written thesis; Create a branch called `thesis-final`
Copy all documents (proposal, thesis, pptx) to SVN:/theses/tkn/<year>.<thesis-type>.<bibtexkey>

After fulfilling the tasks, report the information to your supervisor via email and they will update the status column.

For the supervisor: Check *After the thesis is submitted* point in How to supervise a thesis page