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| **Abstract:** | Today’s students are tomorrow’s engineers. Early exposure to standardization work, best started during undergraduate years, will help to demonstrate the benefits and importance of standardization to students of engineering. FG ML5G ran a pilot project between May and December 2019 to engage university students in FG ML5G’s work. ITU experts mentored 15 students from India, Nigeria, Brazil, Norway and Qatar and introduced them to IMT-2020 and ITU’s ML5G (Machine Learning or 5G) work. At the end of the pilot, nine students from four countries completed their projects and submitted their contributions to FG ML5G. This document lists the benefits of this pilot project for students, ITU and the industry, as well as several factors that played a key role in the success of this pilot. |

**1 Introduction**

Today’s students are tomorrow’s engineers.

For a period of about eight months (May – December 2019), 15 students from India, Nigeria, Brazil, Norway and Qatar were mentored under the guidance of ITU experts and introduced to IMT-2020 and ITU’s ML5G (Machine Learning or 5G) work. At the end, nine students from four countries completed their projects and submitted contributions to FG ML5G. Over the duration of the project, students learnt about formulating problem statements, read papers, wrote code, wrote papers and presented their work to FG ML5G in e-meetings. It was a win-win for many stakeholders, particularly students, professors and industry.

The pilot project was advertised on the mailing list of FG ML5G as well as ITU’s academia contact list. Either an interested professor or a student then initiated the contact with ITU. In both cases, the professors played a crucial part in the student project by playing the role of an “internal” guide, liaising with the university to assimilate the work of the student, arranging resources for the students and in some cases awarding academic credits for the work of the student.

Experts active in ITU’s ML5G work provided mentoring to the students without which the project would not work.

**2 Benefits**

This initiative brings several tangible and intangible benefits to the student community, ITU and our industry partners. This clause lists some of these benefits observed in the pilot projects.

**2.1 Benefits for students**

There was consistently positive feedback from students and professors. It was recommended that this project gets promoted at the university level and also looks for the support from the university management to include broader participation of students and professors.

NOTE- see Appendix I for feedback quoted from students and mentors.

* **Skills development**. The students mentioned that they have learnt relevant concepts about standards, their impact and also new concepts, e.g. “5G architecture and concepts”, “How to save energy in networks with ML”, “How to distribute ML tasks across user equipment, edge devices and IoT devices”, “Working with edge computers to communicate over servers in the cloud” and more. Students were able to complement the theoretical concepts learnt in the classroom with practical hands-on experiments using opensource. Thus, with the help of mentors from ITU, students found it interesting to apply the theoretical concepts to practical problems discussed during the project.

In addition to learning new concepts, students have acquired other skills such as the utilization of specific software in both ML and networking fields (Wireshark, Komondor, Adlik, Openbaton, Open Network Automation Platform (ONAP), ML libraries, related models and tools).

* **Networking**. Communicating with ITU experts was a golden opportunity for students to enhance their skills. Being part of this pilot project has helped students to figure out multiple facets of the domain and gain confidence in general. The students had the opportunity to meet and work with a wide network of experts within the scope of the project and create a network of peers from all over the world. At least one student was offered an internship from a major equipment vendor following this project while others found the knowledge gained from the projects useful in their career paths. Another project has been acknowledged with acceptance of the student paper and demo for showcasing in a regional forum of ITU.
* **Academic credits for student studies.** The universities in some countries (e.g. Nigeria and India) adopted the policy to grant academic credits (e.g. four credits) for working on projects in FG ML5G. It was an important motivation factor and helped to build the engagement. This also helped deeper collaboration with those universities during the project work and in many cases planning for follow-up projects.
* **Access to specific information/documents** which are not available through public media or literature. The methodical and meticulous approach of documentation, concepts of Machine Learning Function Orchestrator, data modelling, use cases, standards gap analysis etc were available to the students via this engagement. While the open access to the documents under FG helped, it was the guidance and hand-holding during the project to navigate the relevant documentation which differentiated this effort from other in-campus initiatives.
* **Guidance to OpenSource**. The students learned about latest technology and tools. Industry partners were also pleased to know that the students regularly tested the opensource contributions from them which helped to improve the projects in Github. One noteable example was that the FG ML5G liaison with the Linux Foundation helped the students to use the Adlik platform from ZTE to study the various factors in model optimization covered in the FG documents.
* **International Recognition**. A “letter of appreciation” was awarded to students who finished the study projects and presented the contributions to FG ML5G. The letter includes specific mention of contributions including feedback from the mentors. This recognition is not only motivating for the students, but also provides a differentiating factor for students the crowded career paths.
* **Enhanced Curriculum of professors through mentoring**. Through this pilot project, ITU has taken the initiative to define a well established mentoring method. Its flexibility is the key to handle the work of students across the globe while adapting to the local needs.

**2.2 Benefits for ITU**

ITU specifications such as ITU’s ML5G architecture and use cases were introduced to the students. In many cases, the students and professors gave valuable feedback regarding the technical content; the interaction could attract future collaboration opportunities.

In essence, the value for ITU is that we get new content and contributions, a fresh wave of “outside the box” ideas. Thus it is a rewarding way of engaging youth in technical work. In addition, there is an opportunity to enlarge the community of experts working on the topic and prepare the future generations of experts for ITU.

A list of 8 student contributions is given in clause 5 of this document. The students presented these contributions in the weekly e-meetings of FG ML5G, which resulted in feedback and discussion by experts in the group. Increased local participation in the regional activities of ITU is another tangible by-product. For example, [[ML5G-I-170-R1](https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-170-R1.docx)] is selected for presentation at the 7th SG13RG-AFR meeting, 5-6 February 2020, Abuja, Nigeria.

The following student contributions are examples where FG ML5G benefitted:

* [ML5G-I-206] studied the optimization mechanisms for ML models. A valuable literature survey was presented to FG ML5G and helped FG ML5G in the discussion with Linux Foundation AI projects. One of the open source projects which uses FG ML5G specifications (Adlik, a project of LF AI, an umbrella foundation of the Linux Fondation that supports open source innovation in AI, ML and deep learning) was used in benchmarking in this student project.
* [ML5G-I-201] was directly related to the data handling work done in FG ML5G. This student project helped FG ML5G to investigate an alternate approach and study the tradeoffs between various approaches.
* [ML5G-I-197] was investigating the approaches used to implement the ML intent defined in [ITU-T Y.3172]. This helped us to understand the similar efforts in metalanguages and their capabilities.
* [ML5G-I-209] helped us to understand the extension capabilities of existing orchestrators and gave practical dimension to the requirements and architecture studies in FG ML5G.
* [[ML5G-I-182](https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-182.docx)] helped us in our discussion with one of our industry partners. The output of this project was shared with the partner.
* [[ML5G-I-173-R1](https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-173-R1.docx)] helped FG ML5G to discuss with other SDOs the metadata regarding machine learning.

Creating mindshare among student researchers, kick-starting opensource contributions in the areas where ITU has collaborations, understanding regional use cases and perspectives were some of the other benefits accrued during this pilot stage.

**2.3 Benefits for industry**

* **Research inputs from academia:** Our industry partners have appreciated the opportunity to obtain research inputs from professors and students on research areas related to the ITU standards. In many cases the views and perspectives are completely different from the ones in academia and quite interesting. It also helps to have a longer term view from the academia which is abstracted from the work item view of the ITU groups.
* **Understanding regional perspective:** The distributed student community offers a chance to understand the limitations and strength of various markets. The challenges in offering connectivity to various parts of the world is best understood by interacting and giving a regional spin to projects. It is best done by local students.
* **Benchmarking and testing inputs and open source contributions:** The student contributions including testing and benchmarking have helped increase the quality of platforms offered by the industry. A good example is [ML5G-I-206] which directly tested the open source tool from one of our industry partners and helped improve it.
* **Identifying practical talent:** Industry gets first hand exposure to evaluating talent in the campus. At least in one case, the industry partner offered an internship to the student.

**3 Success factors**

Commitment from mentors and students is the single most deciding factor for achieving this. These and other factors are detailed below.

* **Commitment from mentors and students:** The single most important success factor was the commitment of mentors and students to the project. A mentor must dedicate a considerable amount of time (between 1 and 2 hours per week for each project) in order for the project to succeed. Similarly the student should spend 3 to 4 hours per week on the project. Thus, academic support in the form of credits or guidance becomes important to balance the pressures of academic life with this additional work.
* **Alignment of the project with course work**: It is important that the project chosen by the student is aligned with the focus of the advisor or regular course work. This way, students are able to associate the project better with the regular course work in the university. This also allows cross-breeding of ideas and stimulate contributions from university to ITU.
* **Support from university or host**: In many countries, “official” recognition of the ITU student project by the university or the host organization motivates the student. Recognition may be in the form of participation of the advisors or professors in the regular project e-meetings or regular feedback to the students. Since the student works from the university and does not travel anywhere for the project, it is even more important that the university or the host institute recognises the effort invested by the student.
* **Seeding of material and presentations**: Since in most cases students are new to the work in standards and ITU, it is necessary to spend considerable time ramping up the students. This can be in the form of walk-through of reference material, open discussions led by the mentors, or presentations based on a literature survey by students. This helps in building up the students’ skill and guiding the discussions towards the final aim of a meaningful project and valuable report.
* **Regular e-meetings**: The student community for these ITU projects are distributed across the world. This necessitates e-meetings by the students and mentors to discuss the projects. Punctual, regular e-meetings are very important for the success of the project. Irrespective of the progress (or the lack of it), regular discussion helps in moving the project forward.
* **Use of opensource**: In many cases, universities are short of funds to procure proprietary software, tools and hardware setups. Opensource software and simulators are the best bet for student projects under such circumstances. It not only allows learning by experimenting but also provides low-cost setups.
* **Availability of an open review platform**: The research direction taken by the student, the tools selected for practical studies and the results obtained need to be reviewed in a transparent way by experts. This can also be an opportunity for the students to get first hand feedback from the industry partners. For example, focus group provide an open platform for presentation and discussion by non-members of ITU (which includes many academic partners). It also comes with logistical and secretariat support.
* **Presence in social media**: Students in many countries use various social media platforms, e.g. Wechat in China, WhatsApp in India and the Middle East, Skype in the US and Europe, and many others. It is important to reach out to students on their locally preferred social media platform to engage them regularly and respond to them promptly. This not only facilitates technical discussions and clarifications, but also helps exchange documents and ideas.
* **Secretariat support**: Additional support like maintaining a student mailing list, a Zoom account to setup e-meetings at short notice, posting of student contributions as per ITU template and finally arranging appreciation letters for students requires effort, and ITU secretariat support is much appreciated for this.

Students, professors and mentors are engaged in this pilot project on a voluntary basis. It is important to involve more mentors in each student project, which may help each specific project to be richer in content and gain extra visibility. Promoting this initiative among universities will go the extra mile to ensure its scalability.

As the next step, it will be important to launch the call for mentors addressed to ITU Academia members (over 160 entities) and other universities to get engaged in this project. In addition, it will be important to explore collaboration with industry to look for open source solutions that the students can use.

**4 Proposal**

The proposal is to invite other focus groups or study groups to replicate this pilot project, taking into account the support from participants and the availability of resources.

**5 References**

* **Details of the student projects:**

[ITU-T ML5G-I-174] ITU-T FG ML5G projects for students <https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-174.docx>

[ITU-T [ML5G-I-177](https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-177.docx)] ITU-T FG ML5G progress report to ITU-T SG13 <https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-177.docx>

* **Student presentations:**

[ML5G-I-206] “Optimization of Machine Learning Models in Distributed Architecture” <https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-206.docx> : this contribution includes practical studies on Tensorflow models and Adlik tool.

[ML5G-I-201] “Level 3 compliant data handling for integration of ML pipeline in future networks including IMT-2020” <https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-201.docx> : this contribution studies the application of Richardson maturity model on REST APIs for ML.

[ML5G-I-197] “FGML5G - Network Service Definition" <https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-197.docx> : this contribution studies the application of metalanguages for ML service definition.

[ML5G-I-209] “Requirements and design of Plugin Module for MLFO” <https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-209.docx> : an opensource tool for orchestration is studied for ML function orchestration.

[[ML5G-I-182](https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-182.docx)] “Approaches for managing ML state in a distributed environment” <https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-182.docx>: the work focused on network mechanisms including declarative specifications for ML services, data handling in 5G for ML, and orchestration mechanisms for ML

[[ML5G-I-173-R1](https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-173-R1.docx)] “Metadata requirements for ML models”<https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-173-R1.docx>: the work focused on ML mechanisms including efficient training, compression, and discovery of models, as well as distributed training. This report was found useful in FG ML5G analysis of related technologies.

[[ML5G-I-170-R1](https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-170-R1.docx)]“Use cases and solutions for migrating to IMT-2020 networks in emerging markets” <https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-170-R1.docx>: Two students developed the concept of an AI-based class room, which aims to provide natural language processing (NLP) based content selection for school students. The work included a hands-on, exciting demo.

[[ML5G-I-168](https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-168.docx)] “Use case setups and test setups for network slicing” <https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-168.docx> : different use cases for network slicing is studied.

* **ITU-T SG13 / FG ML5G specifications:**

[ITU-T Supplement 55] ITU-T Supplement 55 to Y.3170-series: Y.ML-IMT2020-Use-Cases “Machine learning in future networks including IMT-2020: use cases”

[ITU-T Y.3172] ITU-T Recommendation Y.3172 “Architectural framework for machine learning in future networks including IMT-2020”

[ITU-T Y.3173] Draft ITU-T Recommendation Y.3173 “Framework for evaluating intelligence levels of future networks including IMT-2020”

[ITU-T Y.3174] Draft ITU-T Recommendation Y.3174 “Framework for data handling to enable machine learning in future networks including IMT-2020”

**Appendix I: Feedback regarding pilot projects**

NOTE- feedback is quoted with written consent from the source (students or mentors).

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| Project | Institute | Feedback (quoted) |
| [ML5G-I-201] | PES university, India | “*The project was relevant because it provided an opportunity to research and learn about 5G network design, machine learning and network orchestration. These topics were introduced as courses in college. Hence, it was interesting to do projects based on them.* *I learned many new concepts like Umbrella Information Model, YANG, Richardson Maturity Model, RESTful API, etc.* *I would definitely recommend it to other students and have already done so.*”  |
| [ML5G-I-206] | PES university, India | “*The project had a lot of information on interesting subjects like machine learning, optimization and networking.**Learnt many interesting techniques on compression and optimization of ML models and also a few machine learning platforms.*”  |
| [[ML5G-I-170-R1](https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-170-R1.docx)] | FUT, Minna, Nigeria | “*We have applied theoretical concepts delivered to us in class practically. As it stands, we plan to use the project as our final year project in school. Undertaking the project has been very educative.**We learnt a lot of new concepts, including the following:** *Future networks including IMT-2020 networks*
* *How to save energy in networks with ML*
* *Using ML to optimize 5G coverage by effectively switching between access nodes*
* *How to distribute ML tasks across UEs, edge devices and IoT devices*
* *Working with edge computers to communicate over servers in the cloud* “
 |
| [ML5G-I-197] | NTNU, Norway | “*Very relevant as I am a communication networks student and 5G networks are already part of our curriculum.**Network function virtualization, network orchestration, and network services’ definition through TOSCA modelling language were the main concepts learnt.**Mentoring is excellent and the mentors take special interest in guiding the students and also giving them the space to learn and be creative.**The project and mentoring are excellent means to introduce students to latest technologies, standardization processes and research methods. Hope this continues and benefits more and more students.*” |
| Mentor feedback | Universitat Pompeu Fabra (UPF), Barcelona. | “*The student was very involved in the project, and willing to learn about the application of ML to networks. The knowledge acquired during the project seems also to complement the main academic activities of the student.**The student has learned (and is still learning) concepts of ML (basic notions on supervised and unsupervised learning for classification) and wireless communications (notions on Wi-Fi networks, traffic priority, scheduling). Moreover, the student is acquiring other skills such as the utilization of specific software in both ML and networking fields (Wireshark, Komondor, ML libraries…)**I think the mentoring process is well established and works well. Its flexibility is key to handle the work of students across the globe. Besides, students are doing a great job and seem to be pretty satisfied**I would promote the involvement of more mentors in each student project, which may help each specific project to be richer in content and gain extra visibility. This could be done through a sort of evaluation committee, where mentors/experts spend some time reviewing and giving feedback on their associated projects.* “ |
| [[ML5G-I-168](https://extranet.itu.int/sites/itu-t/focusgroups/ML5G/input/ML5G-I-168.docx)] | PUCPR, Brazil | “*The ITU-T FG ML5G project on ML use cases for 5G was very relevant for me.**I learned a lot of new things!**I learned about network slicing, how it works on different situations and how helpful it is for the ML and 5G.* “ |

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