le cnam

The CNAM-CEDRIC Networks and IoT Systems research group hires between 3 and 4 Ph.D. candidates and/or postdoc in the following topics. A detailed description of the topics is given in the next pages.

Topics

1. Low-Earth Orbit Satellite Networks: Routing and Traffic Management
2. Deterministic Combined Wireless and Wired Access Network Technologies
3. Near-Real Time Multi-Resource Scheduling in Disaggregated Access Networks
4. Distributed Artificial Intelligence for Edge Computing Applications

Research environment

Computer Science and Communications department (CEDRIC; https://cedric.cnam.fr)

Team: Networks and IoT Systems (ROC – Réseaux et Objets Connectés; https://roc.cnam.fr)

Related collaborative projects:
H2020 AI@EDGE: European project on AI for beyond-5G networks, with 19 European partners.
IA ENE5AI: project on integrated 5G and edge computing use-cases, with Gandi, EDF, Celeste, ...
ANR HEIDIS: project on vRAN multi-resource scheduling with UPSaclay, Orange, EDF, SMILE.
ANR PARFAIT: project on distributed AI for edge computing, with UAvignon, UMontBlanc, Inria.

Location:
Paris, France - downtown district (le Marais), third arrondissement. 2 rue Conté, Paris, France.

Period

The contracts can start from May 2022 to December 2022.
The Ph.D. duration is 3 years. The Postdoc duration is 2 years.

Salary

PhD: 26000 - 28000 € gross/year depending on experience.
Postdoc: 32000–40000 € gross/year depending on experience.

In addition, 50% of the public transportation subscription can be reimbursed.

Optional: teaching activities in French and/or English for up to 64 h/year, 2 650 € /year.

Requirements

Master/PhD degree in computer science, computer engineering, or telecommunications engineering.

Application

As soon as possible. Send to perm-roc@cnam.fr your preferred subject(s) and:

- An up to date curriculum vitae on maximum 3 pages, including names and contact information of 2 reference persons (professors or industrial tutors).
- University/engineering degree transcripts for the last 3 years.
- Copy of all your master/bachelor thesis and/or internship report(s).

1 – Low-Earth Orbit Satellite Networks: Routing and Traffic Management

Many thousands low-earth-orbit (LEO) satellite are already operational, launched by companies as Amazon, Telesat, Starlink; for instance, the latter alone comprises almost 2000 LEO satellites in early 2022. While the geostationary earth orbit (GEO) satellites latency makes them not attractive for interactive Internet usages (with one-way-delays above 120 ms, a client-to-server round-trip time can easily take half a second), the communication latencies LEO satellites can grant are much shorter. They do depend on the actual LEO distance that can range from few hundreds km to two thousand, hence with one-way air-travel delays between 1 ms and 7 ms. This setting clearly makes LEO communications competitive with ground long-distance fiber optical communications for Internet/cloud access services. While theoretically only ground links can reach the shortest distance over a straight line, in practice they are not, and the ground latency can also increase because of intermediate optical-electronic conversion and queuing delays.

Technical disadvantages of LEO communications are many, however. Namely, a communication spatial cone that decreases with the distance from earth, along with the need to mechanically correct the orbit on a regular way, hence possibly inducing a shorter lifetime than GEO satellites. Moreover, the possibility to have on-boarding computing nodes is strongly constrained by the heating capacity, challenged by the lack of atmosphere. Nonetheless, these limitations can be compensated by capillary deployment and inter-node direct forward, which eventually can decrease the communication latency for long-haul communications.

LEO networking faces therefore new challenges, such as:

- Routing across multiple ground-orbit and inter-satellite links.
- Packet scheduling combining multiple paths across LEO nodes and links.
- Traffic engineering and dynamic function chaining, as a function of changing propagation physical-layer conditions.
- Topology design, i.e, where to place LEO nodes as a function of traffic, in a 3D space.

The envisioned tasks can be a subset of the following ones:
(i) to build a network simulator by leveraging on existing tools;
(ii) to run a comparative analysis in terms of achievable latency and bitrates between LEO and ground communications, based on real Internet data;
(iii) to work on the topology design problem including both standalone and inter-LEO-node communications;
(iv) to evaluate the impact of hybrid satellite-ground network settings on routing stability and transport layer efficiency based on realistic traces on channel conditions;
(v) to propose novel LEO orchestration protocols able to support dynamic function chaining, rerouting and multipath transmission and evaluate them on an experimentation environment to be designed.

Candidates should possess a basic background in signal processing and telecommunications.

References

[1] D. Bhattacherjee et al. Gearing up for the 21st century space race. In ACM HotNets, 2018.
[2] D. Bhattacherjee and A. Singla. Network Topology Design at 27,000 km/h. In ACM CoNEXT, 2019.
[3] Telesat. https://www.telesat.com/, 2019.
[4] SpaceX Starlink. https://www.spacex.com/webcast, 2017.
[5] J. Brodkin. FCC approves SpaceX plan to launch 4,425 broadband satellites. https://tinyurl.com/ybbkgxwp.
[6] A. Boyle. Amazon to offer broadband access from orbit with 3,236-satellite 'Project Kuiper' constellation. https://www.geekwire.com/2019/amazon-project-kuiper-broadband-satellite/, 2019.
[7] M. Handley. Delay is Not an Option: Low Latency Routing in Space. In ACM HotNets, 2018.
[8] T. Klenze et al. Networking in Heaven as on Earth. In ACM HotNets, 2018.

2 – Deterministic Combined Wireless and Wired Access Network Technologies

5G systems are being deployed nowadays mostly in their non-standalone mode that largely leverages on legacy 4G core technologies. Esteemed to still represent only around 1% of the traffic [1], the commercialized services are for conventional mobile broadband services. Expected to reach a 25% traffic portion by 2025 [2], 5G systems will be offering novel and unique services for the IoT and low-latency high-reliability environments.

In particular, the URLLC (Ultra-Reliable Low Latency Communication Services) network slices are being designed to be able to deliver near-real-time traffic processing for advanced low-latency services such as augmented reality or smart industries, and that at unexpected availability and reliability guarantees [3]. In the commercial consumer systems, addressing deployment in dense and loosely predictable communication environments, such low-latency high-reliability performance can today be granted only by wireline technologies. Many examples exist, from smart transportation systems with pervasive network control systems [4], to in-flight airplane communications [5] and smart-grid and smart-industry environments.

In this research activity, we aim at:

(i) Comparing the 5G URLLC access infrastructure to a wireline infrastructure based on deterministic networking technologies such as the DETNET (Deterministic Networking) architecture [6], possibly coupled to TSN (Time Sensitive Networking) IEEE 802.1 systems [7]. The comparison will be made against application use-cases such as those above mentioned. For the vehicular use-cases, the integration of the wireline infrastructure with vehicle-to-infrastructure (V2I) technologies will also be considered.

(ii) Study the possibility to combine 5G access with wireline/V2I technologies in order to further increase access latency and reliability. The usage of recent 5G-WiFi integrated technologies, such as based on MultiPath Transmission Control Protocol aggregators will be considered.

(iii) Investigate cybersecurity threats to the three communication modes (URLLC, wireline/V2I, combined).

Methodologically, the goal is to evaluate the different technology alternatives, also using a private 5G experimental infrastructure operated by the research group at Cnam, making use of customized open-source stacks and software-defined radio systems. The ambition is to enhance the current technologies, defining new access architecture and related scheduling sub-systems in disaggregated softwarized access network platforms.

Candidates should possess a strong background in TCP/IP architecture and mobile computing.

References

[1] E. Bembaron. La 5G représente "moins de 1% du trafic", affirme Bouygues Telecom. 2021. https://www.lefigaro.fr/secteur/high-tech/la-5g-represente-moins-de-1-du-trafic-affirme-bouygues-telecom-20210520
[2] Global 5G connections will more than double by 2025, GSMA predicts. 2021. url: https : / / techmonitor . ai / technology/networks/china-north-america-will-lead-5g-adoption-europe-lagging.
[3] M.A. Siddiqi et al. 5G Ultra-Reliable Low-Latency Communication Implementation Challenges and Operational Issues with IoT Devices. Electronics 2019, 8, 981.
[4] UrbanLoop Transportation Infrastructure (website): https://urbanloop.univ-lorraine.fr
[5] Temprado, E., et al. "In-flight entertainment and connectivity in the 5G era: The 5G ESSENCE experimental platform." 2019 European Conference on Networks and Communications (EuCNC). IEEE, 2019.
[6] N. Finn et al. Deterministic Networking Architecture. RFC 8655. Oct. 2019.
[7] D. Maxim et al, "Delay analysis of AVB traffic in time-sensitive networks (TSN)". RTNS '17. 2017.

3 – Near-Real Time Multi-Resource Scheduling in Disaggregated Access Networks

Open Radio Access Networks (O-RAN) and Software Defined RAN (SD-RAN) platforms are making surface in the telecommunication networks environment with the motivation to let telco providers to emancipate their infrastructures from its ossification due to vendor-lock-in and rigid protocol standardization process. Other motivations to migrate from hardware-locked infrastructure to softwarized infrastructure is to allow more dynamic management of 5G and beyond-5G systems [1,2], to meet the new requirements in terms of bitrate, latency, reliability and scalability of 5G use-cases [3,4].

Among the operations involved in the provisioning of network slices, the joint and coordinated allocation of multiple resources (e.g., radio, link, computing, storage) across independent resource domains (RAN, transport, NFV infrastructure, cloud infrastructure) [5] raises new requirements. In particular, forms of distributed coordination at both the scheduling and the orchestration layers of O-RAN/SD-RAN platforms are required, going beyond existing Cloud-RAN joint scheduling solutions proposed in the literature [7]. Coordinated scheduling across resource domains can avoid resource wastage due to bottleneck at a subset of resources, and is currently envisioned as being decomposed in three execution time horizons: non-real time, near-real-time and real-time scheduling.

The goal of this thesis is to work toward the integration and improvement of existing multi-resource allocation algorithms in an extended O-RAN environment to support multi-domain resource scheduling coordination across the three execution time horizons. The starting point is the recent work in [6]. The activity is expected to pass through the following steps:

- Enhancement of algorithms in [6] to support fault-resiliency of resource controllers ;
- Integration to a combined O-RAN/multi-resource orchestration platform leverating on state-of-the art open-source platforms.
- Enhancement of the algorithmic framework to integrate predictive AI decision-making to leverage on infrastructure data analysis coming from RAN and virtualized infrastructure components.

Candidates should possess good programming skills and a background in SDN/NVF/Linux system integration and administration.

References

[1] 5G Americas. "Network Slicing for 5G and Beyond". WhitePaper, 2016.
[2] NGMN. "5G white paper". Next generation mobile networks, 2014.
[3] 3GPP TS 22.261 V15.5.0, 5G; Service requirements for next generation new services and markets.
[4] O-RAN Use Cases and Deployment Scenarios, White Paper O-RAN Alliance, February 2020.
[5] F. Fossati, S. Moretti, P. Perny, S. Secci, "Multi-Resource Allocation for Network Slicing", IEEE/ACM Transactions on Networking, Vol. 28, No. 3, pp: 1311-1324, June 2020.
[6] F. Fossati, S. Rovedakis, S. Secci, "Distributed algorithms for multi-resource allocation", IEEE Transactions on Parallel and Distributed Systems, 2022.
[7] M. Sharara, S. Hoteit, P. Brown, V. Vèque, "Coordination between radio and computing schedulers in Cloud-RAN", 2021 IFIP/IEEE International Symposium on Integrated Network Management (IM).

4 – Distributed Artificial Intelligence for Edge Computing Applications

Emerging cloud-edge infrastructures supply computing resources in the vincinity of the end user, and are thus well suited to support IoT and AI-driven applications. Nonetheless, it is not straighforward for a service provider to optimally operate on IoT data and exploit AI as a service across IoT devices, edge and cloud nodes, as it needs limited orchestration knowledge and involves the end-to-end management of many functions that are either related to optimizing the operation of the cloud-edge infrastructure or the IoT application.

These functions span the contextualisation, filtering, enriching of the contributed data that serve to train the shared model, which in turn supports advanced AI-driven functions, including, flow prediction, avanced data analytic, anomaly detection based on the contributed monitored data. Rather than uploading the sensed information to a cloud that supports a centralised inference as in classical approaches, a convenient approach lies in keeping and processing localy as much as possible while models are trained and iteratively updated at the edge before being transfered and globally aggregated at the cloud [1].

The project activity will be focused on the following aspects :

- Devising new flexible resource allocation algorithms and sheduling policies to support the chain of AI tasks across several physical nodes that operate on IoT data. This involves optimizing the allocation, making a tradeoff between the resource utilised (versus large model size) and accuracy.
- Following, special care should be put on carefully balancing the resources and quality (e.g. convergence accuracy) of the models. At the edge, local model updates are computationally intensive and transferring data between edges and the cloud for aggregation is bandwidth consuming, which contributes to accuracy. Thus, preserving the specified convergence at minimal resource cost is a challenge that need to be addressed, especially with regard to the resource gluttony of AI applications and the limited resources availability at the edges [2].
- The proposed orchestration system should be capable of making decision and adapt in an uncertain and time-varying environment.
- In addition to the above, the performance associated with the proposed algorithms and policies should be analytically and empiricaly studied.

Candidates should have a master degree in computer science, with a background on networks, distributed systems and AI. Programming skills are appreciated.

References

[1] J. Verbraeken, M. Wolting and J. Katzy, and al. A Survey on Distributed Machine Learning. ACM computing surveys. ACM computing Surveys, 53(2), 2021.
[2] K. Kaur, F. Guillemin, V. Quintuna Rodriguez and F. Sailhan. Latency and network aware placement for cloud-native 5G/6G services. In Consumer Communications & Networking Conference (CCNC), France, 2022.