The Networks and IoT Systems research group of CNAM-CEDRIC hires between 4 and 7 Ph.D. candidates and/or postdoc and/or engineers in the topics below (detailed description: next pages). Master interns applications, for possible continuation in a PhD in these topics, are also considered.

Topics

1. Low-Earth Orbit Satellite Networks: Routing and Traffic Management
2. Deterministic Combined Wireless and Wired Access Network Technologies
3. Integration of Functions and Algorithms in Programmable Network Cards
4. Distributed Artificial Intelligence for Edge Computing Applications
5. Graph Neural Networks for Cyberphysical Systems Security

Research environment

Team: Networks and IoT Systems (ROC – Réseaux et Objets Connectés; https://roc.cnam.fr)
Computer Science and Communications department (CEDRIC; https://cedric.cnam.fr)

Related collaborative projects:

France 2030 6G IE6: Internet of Edges for 6G
IPCEI MECT OpenRAN: project on network automation platforms and algorithms, with Orange.
ANR GNADIS: GNN-based Attack Detection for Cyber Physical Systems
ANR COMMITS: COnverged coMMUnication, control and scheduling Infrastructure for multi pods-based Transport Systems
CHIST-ERA GRAPH4SEC: Graph Neural Networks for Security Applications

Location:

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

Equipe Réseaux et Objets Connectés (ROC) Centre d'Etudes et De Recherche en Informatique et Communications
Cnam. Case 2LAB20 - 292, Rue Saint-Martin - F75141 Paris Cedex 03
https://roc.cnam.fr

Period

The contracts can start from May 2024 to April 2025.
Contract duration: Ph.D. 3 years; Postdoc from 2 to 4 years; Research engineer from 1 to 4 years.

Salary

PhD: about 33 000 € gross/year (2 350 € net/month).
Postdoc: 37 000 – 43 000 € gross/year (2 600 – 3 100 € net/month) depending on experience.
Pre-doc engineer: 29 000 € gross/year (2050 € net/month).

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 theoretically grant are much shorter. Technical challenges 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

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[3] Telesat. https://www.telesat.com/, 2019.
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[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.
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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
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3 – Integration of Functions and Algorithms in Programmable Network Cards

Recent evolutions in programmable boards and cards, for example using Field Programmable Gate Array (FPGA) boards equipped with network cards (NetFPGA), are making them appealing for running distributed network functions. Application-Specific Integrated Circuit (ASIC) systems are also making surface combining FPGA and hardware accelerators.

On the other hand, infrastructure disaggregation technologies are leading to the design of stateless network and service functions, able to be dynamically restored and rescaled at different physical locations to adapt to change infrastructure state conditions. Their stateless nature pushes for their decomposition in microservices, which can be easily offloaded to programmable hardware. Following this approach, multiple core network and radio functions, besides edge computing applications and middle-boxes are implemented entirely or in part using systems as NetFPGA boards.

The aim of this position is to propose methodologies and tools to assess the performance, power consumption and costs of online and lookaside acceleration deployments for network, data-link and physical layer functions and critical ML/AI algorithms, as well as other offloadable functions used by network control applications, and a concrete evaluation with a selected set of hardware.

To achieve this objective, the following tasks are foreseen:

- A detailed analysis of the state of the art will first be carried out to identify candidate technologies (compute, interconnect and memory) to be explored.
- The proposals to be formulated should meet both emerging industrial solutions and current research directions in industry and academia. In addition, standardization initiatives, in particular the O-RAN Acceleration Abstraction Layer, which aims to define a hardware-independent acceleration interface, will serve as a guide to ensure the portability and interoperability of the options studied.
- The proposal should also consider the incomplete knowledge of the energy consumption, pooling gains and exact performance (e.g. baseband processing functions) that can be achieved with the different options

Candidates should possess good background in programming, networking as well as embedded systems.

References

[1] Gondaliya, H., Sankaran, G. C., & Sivalingam, K. M. (2020, December). Comparative evaluation of IP address anti-spoofing mechanisms using a P4/NetFPGA-based switch. In Proceedings of the 3rd P4 Workshop in Europe (pp. 1-6).
[2] Sankaran, G. C., Sivalingam, K. M., & Gondaliya, H. (2021). P4 and netfpga based secure in-network computing architecture for ai-enabled industrial internet of things. IEEE Internet of Things Journal.
[3] Patetta, M., Secci, S., & Taktak, S. (2022, July). A Lightweight Southbound Interface for Standalone P4-NetFPGA SmartNICs. In 2022 1st International Conference on 6G Networking (6GNet) (pp. 1-4). IEEE.[4] Visconti, P., Velazquez, R., Soto, C. D. V., & De Fazio, R. (2021). FPGA based technical solutions for high throughput data processing and encryption for 5G communication: A review. TELKOMNIKA (Telecommunication Computing Electronics and Control), 19(4), 1291-1306.

4 – Distributed Artificial Intelligence for Edge Computing Applications

Emerging cloud-edge infrastructures supply computing resources in the vicinity 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 scheduling 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 utilized (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 empirically studied.

Candidates should have a solid background in networking, distributed systems and AI.

References

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[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.

5 – Graph Neural Networks for Cyber Physical System Security

The application of AI and ML to network security is paramount against cybercrime. While AI/ML is mainstream in domains such as computer vision and natural language processing, traditional AI/ML has produced below-par results in the field. Solutions do not properly generalize, are ineffective in real deployments, and are vulnerable to adversarial attacks. A fundamental limitation is the lack of AI/ML technology specific to network security.

Due to their unique ability to learn and generalize over graph-structured information, graph-learning approaches, and in particular Graph Neural Networks (GNNs), have recently enabled groundbreaking applications in multiple fields where data are generally represented as graphs. Network security data are intrinsically relational, and initial research suggests that graph-structured representations and GNNs have the potential to become foundational to AI4SEC, in the way convolutional and recursive networks were to computer vision and natural language processing.

The goal of this position is to leverage graph data representations and modern GNN technology to conceive a new breed of robust GNN-based network security methods which could radically advance the AI4SEC practice. The envisioned tasks are:

- to investigate algorithmic methods that facilitate modeling and learning from graph-based network security data;
- to compare the benefits and overheads of GNN-based attack detection to traditional AI/ML in terms of detection performance, generalization, scalability, and robustness against adversarial attacks;
- to showcase the benefits and improvements of GRAPHS4SEC technology in four critical, real-world network security applications with significant impact for society, considering (in particular) the detection and early mitigation of phishing and fake/malicious websites, a threat among the most popular and society-wide harmful in today's Internet.The activity is expected to pass through the following steps:

Candidates should possess a good background in AI/ML and network security.

References

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