1. Introduction

Nokia Bell Labs' AAAID research domain focuses on the blending of intelligence into all aspects of everyday life and processes. As devices and sensors become increasingly connected and several autonomous agents with a physical presence make an appearance in smart homes and factories, the need for intelligent algorithms to support machines within complex physical spaces shared with humans becomes a primary driver of our research. The Future X network will be the platform that dynamically provides the knowledge and computing power to support machine interactions at scale. Our ambitious objective is to develop systems that collect and blend information from multiple sources, extract and make sense of the things that matter, and act upon and propagate the resulting knowledge. Our research targets the fields of industrial automation and smart cities.

2. Scope of the Ph.D. Thesis

Interactive media consumption mediums like Augmented and Virtual Reality (AR/VR) will play a key role in industrial automation environment, providing means to display real time contextual information to the users of the architecture (humans or machines). The agents performing the object detection and recognition in an AR/VR system can either be stationary (surveillance cameras) or mobile (drones or robots). In the latter case, mobile AR/VR agents will be faced with wireless limitations and changing network and compute resources brought forth by their mobility. Hence, a key research question in this context is how can mobile wireless AR/VR agents exploit and adapt to their environment to minimize service response time without sacrificing the quality and accuracy of the relayed contextual information.

3. Research Topic

This Ph.D. thesis will focus on developing a distributed processing architecture for mobile AR/VR agents. The end goal of the envisioned system is to assist mobile AR/VR agents in performing accurate real-time context processing tasks, e.g. environment scanning through object detection and recognition. This entails addressing challenges related to optimizing the use of available network and compute resources, coupled with smart offloading techniques, to optimize the quality of the relayed information while achieving milliseconds latency guarantees. Hence, in the context of this Ph.D. thesis, the student will investigate two key research challenges:

- **Low-latency real-time adaptive offloading:** Existing AR/VR solutions are not capable of performing real-time high-rate frame analysis as they remain both compute and power bound. Achieving high detection accuracy at milliseconds granularity is critical in industrial automation environments. Offloading frames to edge or cloud processing units is thus key to achieving low-latency high-accuracy object detection and recognition. Yet, effectively offloading frames to edge processing units hinges on the quality of the wireless medium and availability of sufficient compute resources; both of which are dynamic in nature. Hence, in the context of this Ph.D., the student will study the dynamics of network and compute resources to devise intelligent and adaptive frame offloading techniques. The goal of the developed techniques is to achieve high-accuracy low-latency object detection and recognition. The student will approach multiple research questions towards achieving this goal namely: what frames to process locally? And which ones to drop or offload? At what bitrate to encode the offloaded frames? When to offload and when to hold-off? As well as approaching questions of relaying frames taken from different viewpoints and/or angles to optimize the detection accuracy.

- **Milliseconds object recognition with multi-decentralized media feeds:** Industrial automation environments typically dispose of multiple AR/VR agents that may either operate independently or collaboratively. The multi-agents scenarios brings forth unique challenges and opportunities; on one hand, agents compete for the shared network and compute

resources; on the other hand, the different media feeds relayed by each agent can be combined to optimize their individual and collaborative performance. The Ph.D. student will study the multi-AR/VR agents scenario to design decentralized techniques that enable agents to optimally share the available resources. Further, the student will exploit the opportunity to combine different agent feeds to investigate several interesting optimization avenues, such as the possibility to anticipate an agent's view using another agent's feeds, as well as how to combine multi-agent feeds to achieve milliseconds high-accuracy objects detection and recognition.

4. Qualifications and Skills

We are looking for a highly-motivated candidate who is enthusiastic about developing breakthrough innovations and participate in cutting-edge research in NOKIA Bell Labs.

A diploma or master's degree in communications, computer science or electrical engineering with a focus on embedded systems, as well as a good knowledge in communication networks and programming languages for systems development (e.g. C++, C, python). Most importantly, the applicant should be willing and able to get engaged in novel and disruptive research areas across multiple disciplines, which will require the applicant to readily learn new skills and expand their toolbox.

The applicant should be highly proficient in spoken and written English, and he/she should have the ability to conduct independent research while also collaborating in a multicultural team environment.

5. Application and Contact

Please send applications to: francesco.bronzino@nokia-bell-labs.com, sara.ayoubi@nokia.com, and fabio.pianese@nokia-bell-labs.com. Applications shall include: a cover letter, curriculum vitae, bachelor and master (or diploma) degrees, academic transcript of courses and grades, any other related documents such as certificates and reference letters.

The application process started on August 1st, 2019 and shall conclude as soon as a qualified applicant has been selected.