VELOCe

Designing end-to-end, interoperable mechanisms for verifiable, low-latency audio communication across mixed wired/wireless networks using Wi-Fi 6, BLE and Ethernet technologies.

SETTING THE SCENE

Real-time audio streaming applications, both in private and professional environments, could greatly benefit from a more reliable, low-latency connection. This need is particularly acute in shared wireless environments with flexible deployments and dynamic traffic conditions.

Current solutions often fall short due to the unpredictable nature of wireless environments, complex end-to-end communication paths, and the inability to measure and control latency in real time. Furthermore, existing solutions face challenges when multiple communication technologies must cooperate, when scalability is required, or when used in mobile settings.

The VELOCe project set out to address several highly relevant use cases aligned with the expertise of its partners. One concerns improving conferencing solutions by enabling better wireless presentations, support for more audio channels, and video distribution across larger areas. Another is to expand Bluetooth Low Energy Audio (LE Audio) offerings to accommodate hearables and voice-enabled smart home devices. Finally, the project seeks to ensure reliable, low-latency audio communication over the latest Wi-Fi generation for mission-critical environments, such as audio communication systems in prisons.

FRAMING THE RESEARCH OBJECTIVE

The VELOCe project's objective was to significantly improve the quality of real-time streaming applications, particularly when deployed at scale, in mobile environments, or across diverse technologies. To do so, the partners wanted to leverage the capabilities provided by the latest generation of Wi-Fi and Bluetooth Low Energy (BLE) technologies while addressing the limitations of current off-the-shelf components.

The key technical goals included using the advanced features of Wi-Fi 6, developing innovative Time-Sensitive Networking (TSN) extensions for Wi-Fi, and optimizing BLE platforms for low-latency control and improved coexistence with other wireless technologies.

Moreover, the project prioritized designing end-to-end mechanisms spanning multiple wired and wireless network segments to tightly manage and verify latency budgets. This approach will ensure reliable, low-latency communication, enabling robust and efficient real-time streaming applications.

THREE MAIN OUTCOMES

The VELOCe project made significant advancements across multiple areas:

Firstly, the partners evaluated the performance of several advanced Wi-Fi 6 features through mathematical modeling, simulations, and experiments using commercial off-the-shelf hardware. To address the limited control offered by such components, the team implemented software-based extensions for time-sensitive networking. They also assessed the integration of Wi-Fi 6 with a commercial communications platform designed for critical communication scenarios. A final approach used imec's openwifi platform, which integrates Wi-Fi on FPGA with a comprehensive driver and Linux software stack. Thanks to its open design, unique time-sensitive features could be incorporated to prioritize and schedule traffic while enabling fully controllable OFDMA capabilities. This solution achieved guaranteed one-way latencies below 10ms in 99% of cases, even under mobile conditions. Additionally, the project evaluated wired off-the-shelf components with TSN capabilities for audio distribution, finding their performance nearly equivalent to that of custom-built systems.

Secondly, the project enabled last-hop audio distribution using LE Audio, achieving latencies in the range of 20ms. This was accomplished by integrating a tightly coupled BLE radio and audio subsystem. By orchestrating LE Audio traffic alongside other BLE or 802.15.4 communications, it became possible to simultaneously stream audio and manage IoT interactions. For environments with Wi-Fi, coexistence strategies were introduced to mitigate interference and maintain the performance.

Thirdly, the project advanced interoperable and verifiable end-to-end latency management. The team developed methods to monitor and measure end-to-end latency in real time, creating a programmable in-band network telemetry (INT) framework for comprehensive performance monitoring. This framework was integrated into a network controller capable of managing both wireless (Wi-Fi and LE Audio) and wired network segments.

Overall, the VELOCe project resulted in a deep understanding of the components of end-to-end latency and their interdependencies. It also showed the importance of highly configurable or customized solutions over commercial off-the-shelf devices with limited configurability for meeting stringent Quality of Service requirements.

NEXT STEPS

The key outcomes of the VELOCe project will be further developed and commercialized by the industry partners.

- **Televic** will bring smarter audio and video processing to conferencing platforms that build upon commercial off-the-shelf components with TSN capabilities. It will also continue to monitor and adapt to the low-latency capabilities of next-generation Wi-Fi.
- **Qorvo** will integrate its co-optimized BLE radio, audio subsystem, and coexistence mechanisms into next-generation chips, aiming to secure a larger share of the LE Audio market.
- **e-BO Enterprises** will apply its insights into the latest Wi-Fi capabilities to offer advanced digital solutions for critical communication systems.

The imec research groups will pursue their research on deterministic connected systems, building further upon the customizable openwifi platform.

VELOCe project partners:

The VELOCe project was co-funded by imec, with project support from Agentschap Innoveren & Ondernemen

FACTS

NAME	**VELOCe**
OBJECTIVE	Verifiable, low-latency audio communication
TECHNOLOGIES USED	Wi-Fi, Wi-Fi 6, Bluetooth® Low Energy, LE Audio, Time-Sensitive Networking, Ethernet, network management, telemetry, audio
TYPE	imec.icon project
DURATION	01/04/2022 – 31/03/2024
PROJECT LEAD	Wim Sandra, Televic
RESEARCH LEAD	Ingrid Moerman, imec – IDLab Lab – UGent
BUDGET	2,372,297 euro
PROJECT PARTNERS	Televic Conference, e-Bo Enterprises NV, Qorvo Belgium NV
RESEARCH GROUPS	imec – IDLab Lab – UGent,imec – IDLab – UAntwerpen

WHAT IS AN

IMEC.ICON PROJECT?

The imec.icon research program equals demand-driven, cooperative research. The driving force behind imec.icon projects are multidisciplinary teams of imec researchers, industry partners and/or social-profit organizations. Together, they lay the foundation of digital solutions which find their way into the product portfolios of the participating partners.

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