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Wipro Remote Classroom System Improves Remote Student Learning

Wipro's Remote Classroom Solution (RCS) leverages the OpenVINO™ toolkit for real-time content augmentation and media analytics. The solution utilizes Intel® Smart Edge Open for edge deployment and analytics.

Societal changes and improved technologies are creating a new opportunity for students and teachers across the globe to embrace remote learning. Never has remote learning been embraced to such a large degree as during the current pandemic.

The rush to embrace the new technology has exposed challenges, including lack of uniform internet access, difficulties capturing student attention, and student burnout from concentrating on a screen all day long. It has highlighted the need for device-agnostic delivery of enhanced learning content. From a technology perspective, one of the main challenges is the inability of remote education methods to mimic the traditional classroom experience with the social aspects of working alongside the teacher and fellow students.

Current remote learning platforms are based on 360-degree/planar video streaming, which records three 120-degree fields of vision that are then played on a planar surface. These systems face high streaming latency due to the transport time from the origin server source to the end users. This latency could be dramatically reduced if streamed from an edge compute server. In addition, when these streams are consumed by many students in different areas (where local-to-regional-data-center bandwidth is bad), the network backhaul to cloud-based origin servers becomes congested. A related challenge is consuming content across a wide range of devices (smartphones, tablets, VR headsets, etc.) and catering to price-sensitive markets.

These challenges create a gap between those who can consume the streamed content, and those who cannot. This paper discusses the methodology to implement an edge solution as an origin server (service renderer). The salient features of this solution are:

- Enhances the overall user experience by enabling edge service rendering
- Reduces power consumption in client devices
- Reduces use of backhaul bandwidth in both uplink and downlink
- Reduces user device battery drainage
- Supports a wide range of end user devices, including low-cost handsets that don't have powerful processors

Intel® Network Builders ecosystem partner Wipro has created its Remote Classroom Solution (RCS) to bring together live classroom interaction, multimedia software, and video analytics into an engaging and personalized educational experience. RCS is designed to mimic the experience of live classroom learning for remote students, and it enhances traditional teaching methods through real-time content augmentation.
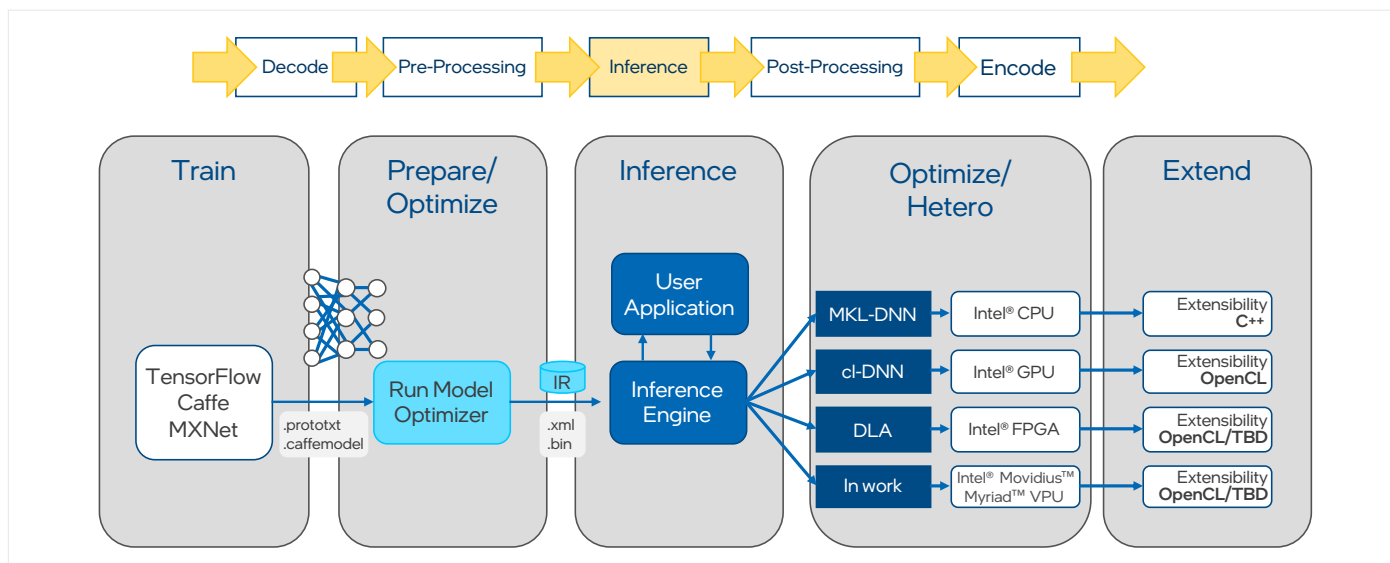
Figure 1. OpenVINO™ toolkit overview.

The solution helps address the gap in access and opportunity of education, and it creates purposeful learning pipelines for students. While a typical classroom setting can be distracting, with the chance of students missing out on important concepts, Wipro's RCS provides multiple personalized educational options. With numerous teaching aids available, the solution can be customized to cater to the different learning needs of students.

Wipro's RCS leverages the OpenVINO™ toolkit for real-time media analytics on a live 360-degree/planar stream. The solution also leverages Intel® Smart Edge Open for edge server deployment, which reduces the latency of the streamed content, and requires zero computational requirements from the end user.

In current learning platforms, all media manipulation and computation are processed in the cloud, including:

- The 360-degree video processing to convert the input 360-degree stream from the camera to an end-user-device-compatible version
- Real-time video analytics on the streams
- Content augmentation on the video streams
- Content caching and retrieval

Wipro RCS provides a solution that offloads the origin server tasks to edge servers. In addition, the solution includes the following.

- Stitching of video streams across multiple cameras and rendering the stitched view to the end user device
- Smart attendance system using face recognition

OpenVINO™ Toolkit Overview

The OpenVINO™ toolkit is built upon artificial neural networks, like convolutional, recurrent, and attention. It is deployed for executing intelligent tasks that require AI and deep learning, such as human vision, automatic speech recognition, natural language processing, recommendation systems, and more. It enables fast and efficient development

of applications that scale across accelerated outputs, optimized results, and deep learning inferences with an easy-to-use library for computer vision (Figure 1).

Intel Smart Edge Open Overview

Intel Smart Edge Open is a royalty-free edge computing software toolkit that enables highly optimized and performant edge platforms to on-board and manage applications and network functions with cloud-like agility across any type of network.

RCS multimedia and video analytics services are offloaded to an Intel Smart Edge Open-powered edge node. Intel Smart Edge Open provides one-click deployment of content and management of its lifecycle. The media and video analytics services run locally to the edge node for greater performance.

Intel Smart Edge Open provides the following benefits for RCS:

- Support for multiple access technologies, including 5G, LTE, Wi-Fi, and wired networks.
- Edge orchestration: Exposes northbound APIs to a central orchestrator, such as Open Network Automation Platform (ONAP), for edge orchestration.
- Range of deployment: Can be implemented either at the on-premises edge or the network edge.

An Intel Smart Edge Open system consists of one or more edge nodes, which support edge applications and network functions, and a controller, which manages the lifecycles of the edge nodes and provides common services for Intel Smart Edge Open edge nodes.

An Intel Smart Edge Open edge node (see Figure 2) hosts a set of building blocks, edge compute applications, and network functions. Edge applications may run natively on an edge node, or may run on an external platform linked by a local breakout port. Traffic from an end-user is steered to edge applications on an edge node via policies configured in the network and routing within the edge node.
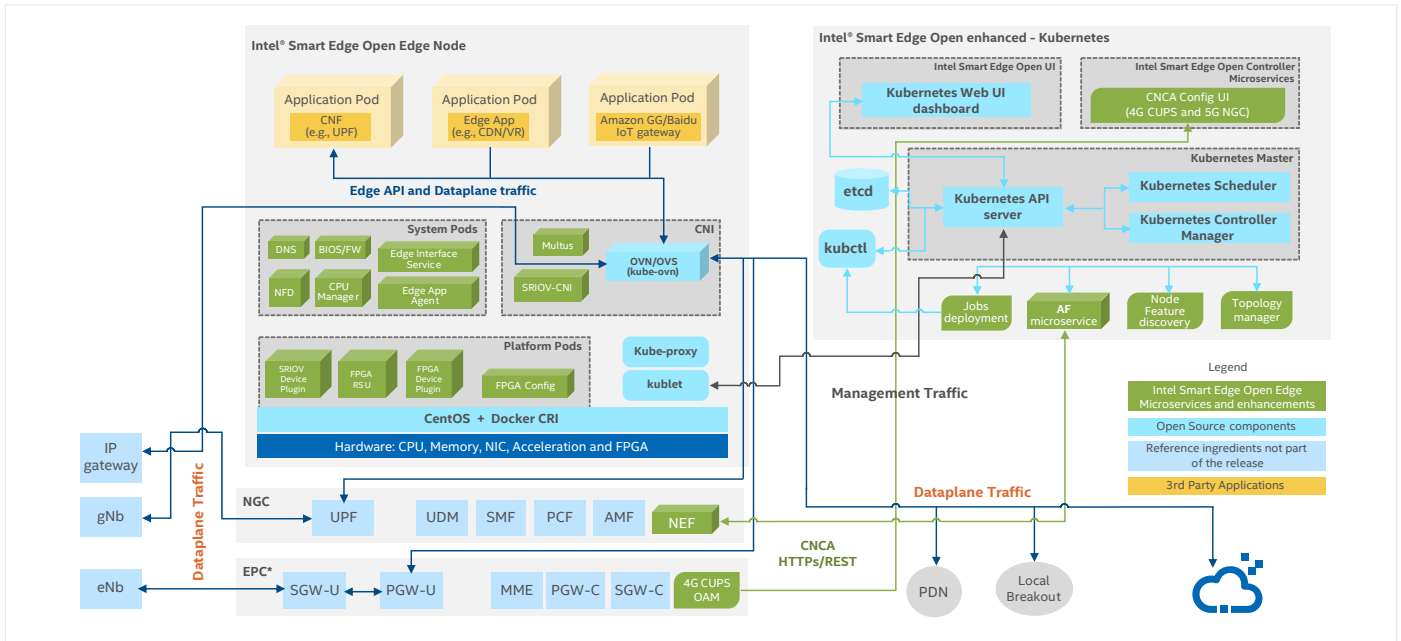
Figure 2. Intel Smart Edge Open architecture used for an RCS application.

The Intel Smart Edge Open controller (see Figure 2) enables management of potentially massively distributed edge platforms. The Intel Smart Edge Open controller manages the lifecycles of edge nodes and schedules the execution of network functions and applications across available edge nodes. The controller can take advantage of network topology and system load, as collected from telemetry, to schedule functions and applications in an optimal manner. The controller may be hosted locally or in an enterprise or public cloud.

The immersive content processing block of Wipro's RCS processes the 360-degree live video feed from the classroom to make it end-device compatible and streams to remote students. The immersive content processing block uses the Intel Smart Edge Open architecture to share content from the media player application, with the remote students using a service subscription-based application architecture.

The edge node has four functions for remote classroom implementations:

1. **Intel Smart Edge Open data plane services:** Steers traffic toward applications running on the edge node or the local breakout port. Traffic policies are configured on the Intel Smart Edge Open edge controller and pushed to the data-plane services. Traffic steering redirects traffic to edge applications for further processing or passes packets through the downstream interface to the packet core for traffic forwarding.

2. **Intel Smart Edge Open enhanced platform awareness microservices:** Building blocks include edge authentication agent (EAA), edge virtualization agent (EVA), edge lifecycle agent (ELA), syslog, domain name system (DNS), and others. They manage application lifecycle, DNS resolution, application enrollment, and more.

3. **Evolved Packet Core (EPC):** The edge node is attached to the SGi interface of an EPC. Traffic from the EPC arrives as IP traffic, and is steered as needed to edge applications.

The EPC combines user and control planes.

4. **RCS application** The media manipulation engine and video analytics engine run either as VMs or as Docker containers.

Intel Smart Edge Open supports containerized applications. The RCS workloads run as a collection of containers. A template for RCS is created by Wipro, with the possibility to be customized by RCS users, and used by Intel Smart Edge Open to deploy RCS on the edge nodes.

Overview of Wipro Remote Classroom Solution

The RCS uses a virtual manipulation and analytics engine deployed on edge nodes to stream real-time 360-degree content to remote students with added capabilities to stream augmented 2D and 3D content to provide an immersive experience for the students to learn and view the topics in real time. The system also provides archived content from previous classes, and it allows real-time teacher-student interaction.

Wipro's RCS (see Figure 3) provides an immersive learning experience to all the students accessing the classrooms remotely. The RCS solution has the following components:

- **Immersive Content Processing:** This block converts 360-degree videos into MPEG-DASH format for easy and real-time access over the web. This also eliminates end-device compatibility issues as the DASH videos can be streamed from an HTTP web server to a browser-based media player.

- **Video Augmentation Block:** A video augmentation control that enables ingestion of 2D and 3D content over the live and cached video streams over the internet.

- **Video Analytics Engine:** A video analytics engine based on a convolutional neural net (CNN) model from the OpenVINO toolkit for detecting students in a classroom. It allows teachers to monitor attendance and engagement of students in the remote classroom.
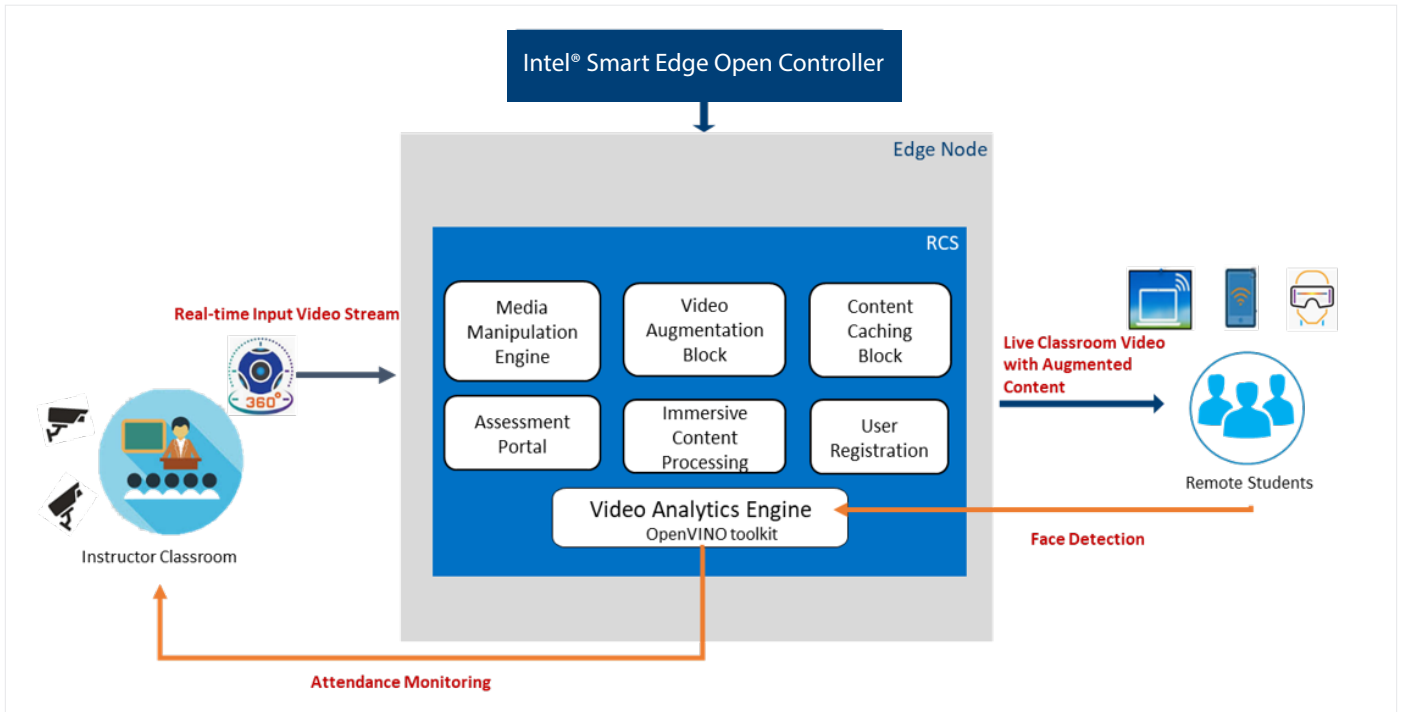
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Figure 3. Wipro's Remote Classroom Solution (RCS).

- **Content Caching Block:** This block is responsible for archiving and retrieving the 360-degree/planar live video streams.
- **Media Manipulation Engine:** This block stitches video streams across multiple cameras and renders the stitched view to the end user device.
- **Assessment Portal:** This block provides teachers and students with the functionality to conduct or take online assessments. These assessments can include questions that require objective or subjective answers, and they include logic to automatically evaluate both types of answers using natural language processing.
- **User Registration:** This is a front-end interface to register a new teacher or student.

End-to-End Solution Architecture

The OpenVINO toolkit provides an inference engine, pre-trained models, and model optimizers. A model optimizer is a cross-platform command-line tool that converts a trained neural network from its source framework to an open-source, nGraph-compatible intermediate representation (IR) for use in inference operations. The inference engine manages the loading and compiling of the optimized neural network model, runs inference operations on input data, and outputs the results.

The video analytics block (using the OpenVINO toolkit) provides inference output to other blocks of RCS as shown in Figure 4.
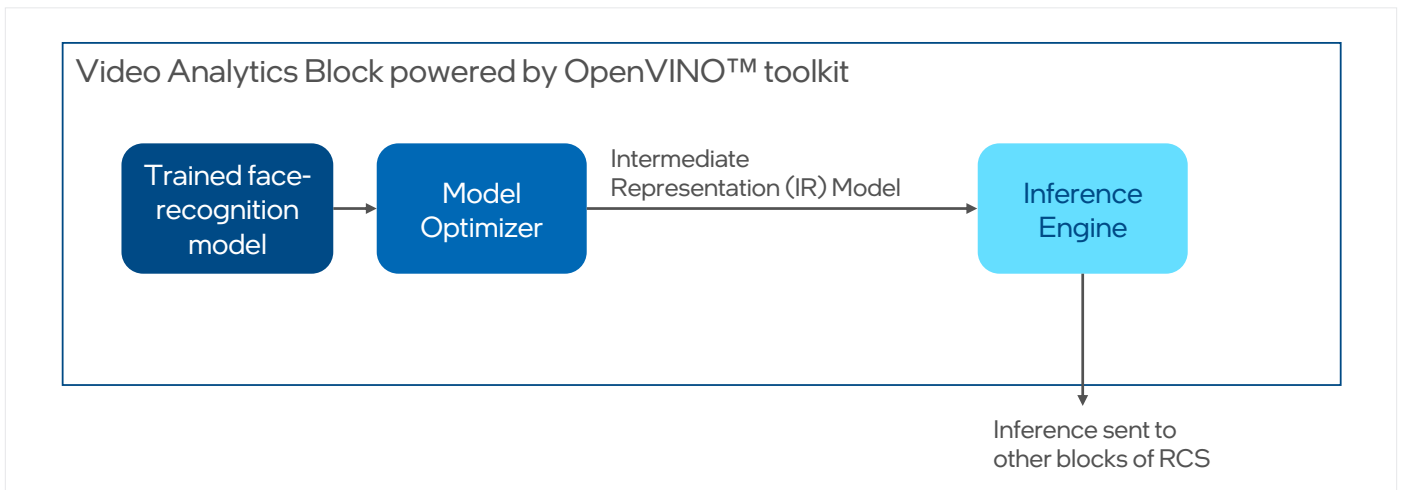

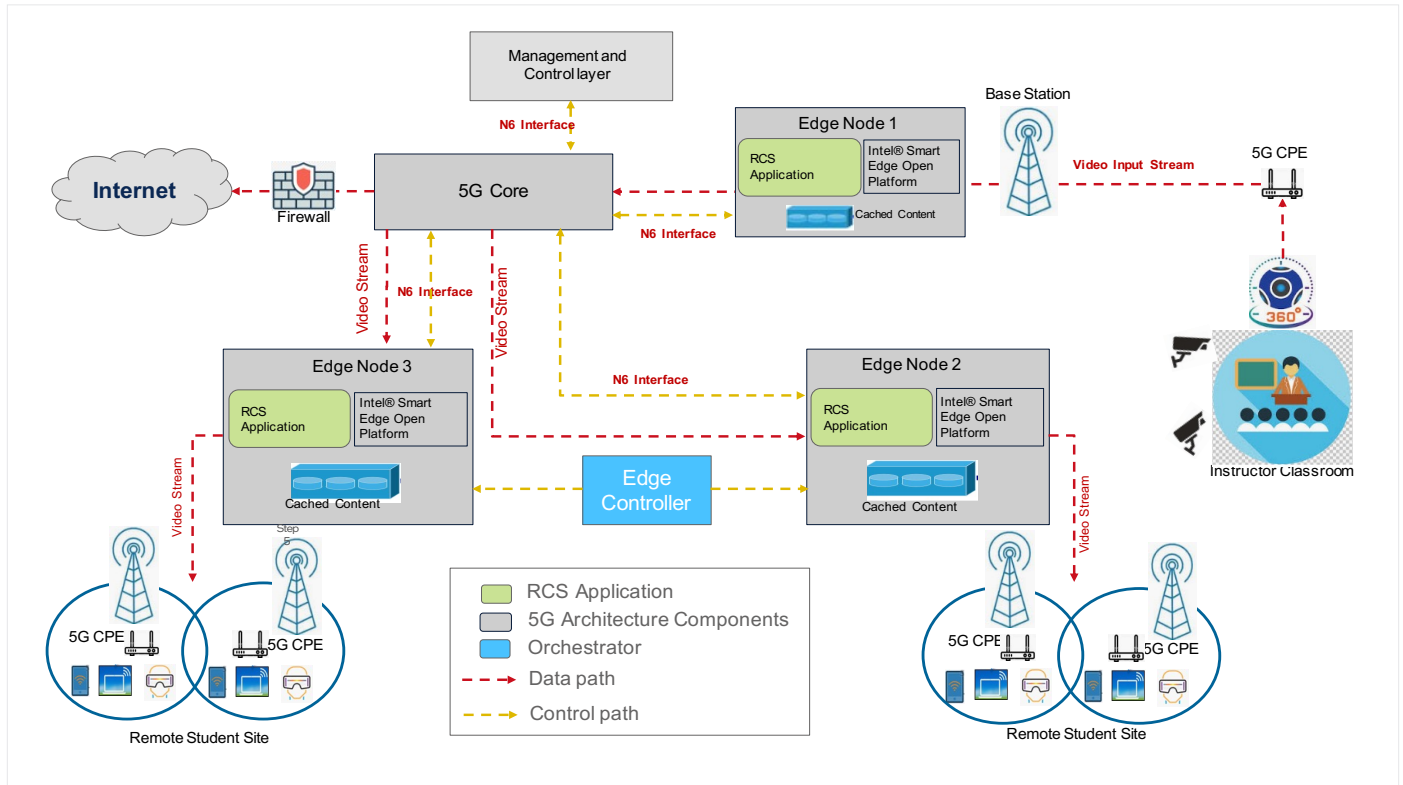**Figure 4.** OpenVINO toolkit with Wipro Remote Classroom Solution.

Figure 5. Wipro's Remote Classroom Solution (RCS) interfacing with 5G architecture leveraging Intel Smart Edge Open.

As shown in Figure 5, the RCS solution is packaged as a Docker container that is then onboarded into the Intel Smart Edge Open edge node via the Intel Smart Edge Open controller. The upstream interface is connected to the video feed from the instructor's classroom. The downstream interface is connected to the remote student site.

Figure 6 shows how RCS is deployed on the edge node. Once the interfaces are declared as user plane interfaces, the RCS application container is deployed on the edge node using the controller user interface. When the RCS container status is changed to running state, the source filter is applied on the RCS container to redirect traffic to the RCS application. The processing required for attendance monitoring (face-recognition) and real-time content augmentation is offloaded to the nearest edge computing node. Once the processing is complete, a lightweight analytics report consisting of the

attendance status is communicated back to the teacher across the backhaul. In this way, the backhaul consumption is optimized, and latency is reduced drastically. This solution uses computer vision libraries from the OpenVINO toolkit to process the video frames and detect faces for attendance monitoring and adds 2D and 3D content on teacher demand.

Model Performance with and without the OpenVINO toolkit[1]

To demonstrate the performance advantage of the OpenVINO toolkit, Wipro conducted tests of frame-by-frame face detection performance of RCS using OpenVINO against an alternative, open source convolutional neural network (CNN) model. The latter approach uses the OpenCV deep neural network (DNN) and an Open Neural Network Exchange (ONNX) format-based model on a fixed-sized frame.
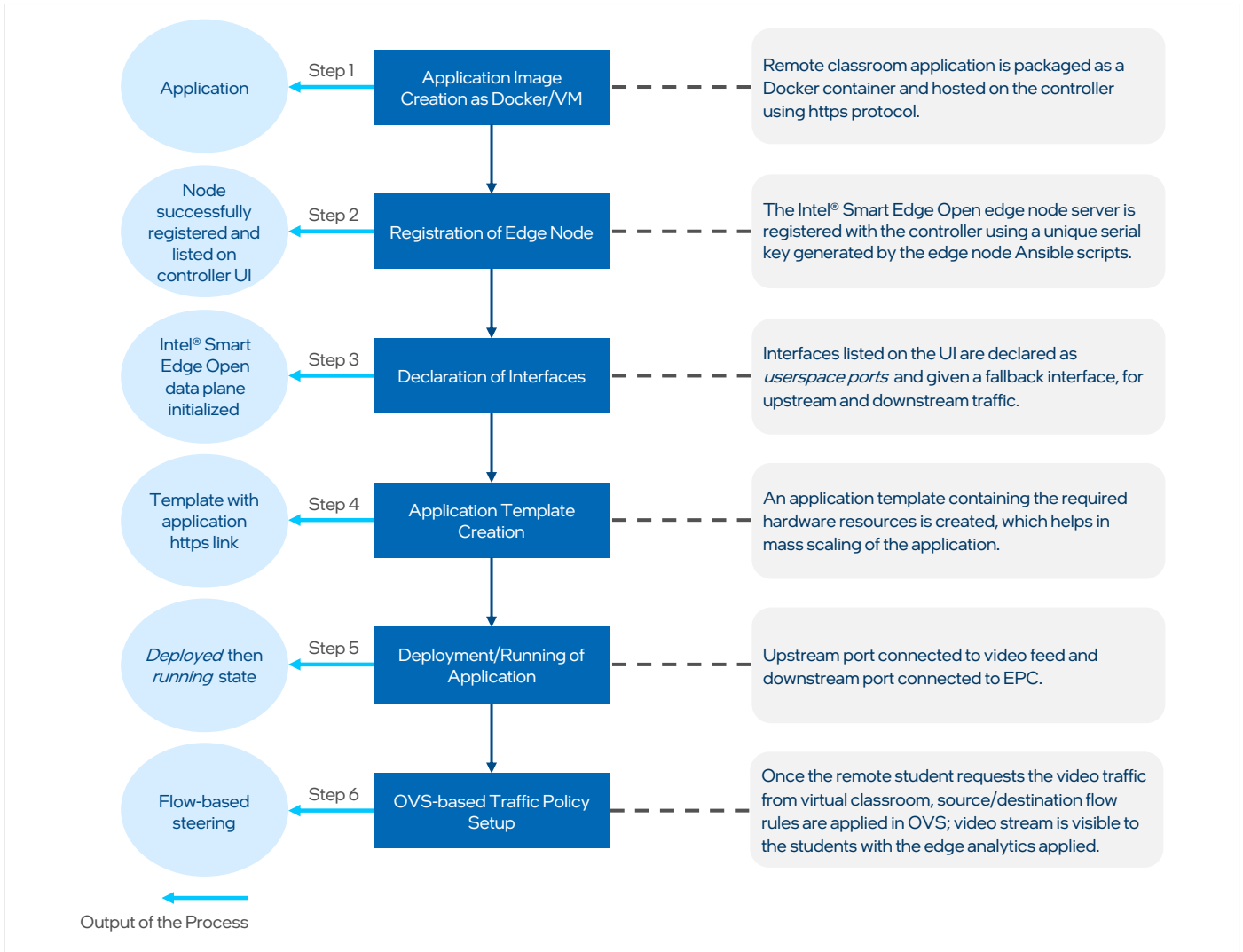
Application	← Step 1	Application Image Creation as Docker/VM	Remote classroom application is packaged as a Docker container and hosted on the controller using https protocol.
Node successfully registered and listed on controller UI	← Step 2	Registration of Edge Node	The Intel® Smart Edge Open edge node server is registered with the controller using a unique serial key generated by the edge node Ansible scripts.
Intel® Smart Edge Open data plane initialized	← Step 3	Declaration of Interfaces	Interfaces listed on the UI are declared as *userspace ports* and given a fallback interface, for upstream and downstream traffic.
Template with application https link	← Step 4	Application Template Creation	An application template containing the required hardware resources is created, which helps in mass scaling of the application.
Deployed then *running* state	← Step 5	Deployment/Running of Application	Upstream port connected to video feed and downstream port connected to EPC.
Flow-based steering	← Step 6	OVS-based Traffic Policy Setup	Once the remote student requests the video traffic from virtual classroom, source/destination flow rules are applied in OVS; video stream is visible to the students with the edge analytics applied.

← Output of the Process

Figure 6. Flow diagram for application deployment on edge.

Time Taken to Process Each Frame (Lower is Better)

Processing time (ms) — nth Frame processed

- ●— Processing time with OpenCV (no OpenVINO toolkit)
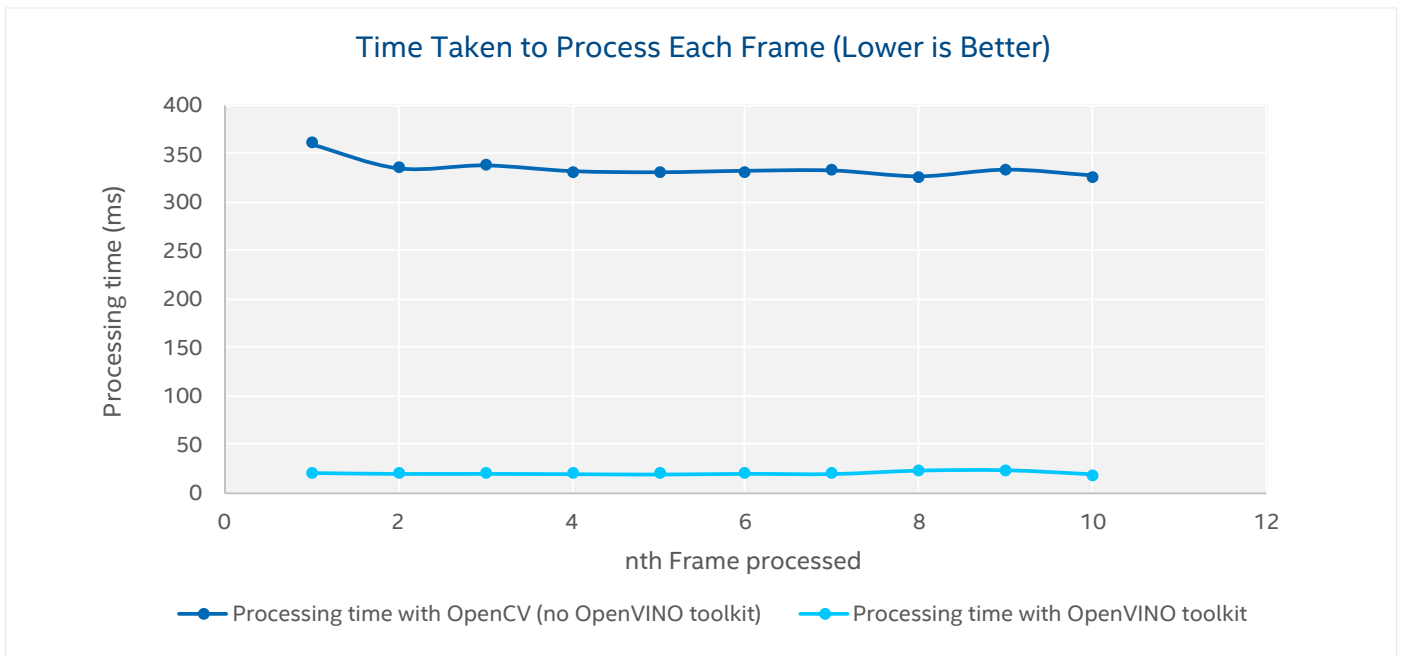- ●— Processing time with OpenVINO toolkit

Figure 7. Graph depicting variation of processing time per frame with and without the OpenVINO toolkit.

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As seen in Figure 7, the OpenVINO toolkit provides faster execution of the deep learning model used for face recognition. Across all frames, the performance of OpenVINO is orders of magnitude higher than the OpenCV configuration.

Both software stacks used a sequence of neural networks and the "face-detection-adas-0001," pre-trained model from OpenVINO toolkit Open Model Zoo.

Conclusion

Wipro's RCS caters to all the needs of remote learning environments such as one-on-one interaction, augmented teaching models, and attendance monitoring for teachers and administrators. The RCS solution provides enhanced learning experiences like real-time content augmentation, voice/video-based interaction, 360-degree live streaming, and more. It also delivers an enhanced customer experience while minimizing the provider's cost of operation. By using Intel Smart Edge Open, the processing of the video analytics can be offloaded to edge compute nodes, allowing video processing locally to minimize backhaul traffic. Orchestration can be leveraged to replicate the RCS across multiple edge instances based on network size and need. The Wipro RCS, powered by the OpenVINO toolkit and the Intel Smart Edge Open edge platform, changes the learning curve for students—even if they are in a remote location; removes worries of device compatibility; and provides a fast, easy way to access classes in an immersive environment.

Learn More

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TABLE OF ABBREVIATIONS

API	Application Programming Interface
CNF	Container Network Functions
CNN	Convolutional Neural Network
DNS	Domain Name System
DPDK	Data Plane Development Kit
EAA	Edge Application Agent
EDA	Edge Data plane Agent
ELA	Edge Life-Cycle Agent
EPC	Evolved Packet Core
EVA	Edge Virtualization Agent
ONAP	Open Network Automation Platform
OpenVINO toolkit	Open Visual Inference and Neural network Optimization toolkit
RCS	Remote Classroom Solution
SME	Subject Matter Expert

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