

The Intel logo is displayed in white lowercase letters on a white rectangular background. The background of the entire page is a night cityscape with a network overlay of white lines and nodes connecting various points across the scene.

intel.

# 5G Networks

Enabling Digital  
Transformation of Smart Cities  
and Intelligent Transportation

# Team

## Author

Suman A. Sehra  
Senior Global Director,  
Smart Cities and Transportation, Intel® Corporation

## Project Managers

Jay Gude  
Business Development and Platform Solution Engineering,  
Smart Cities and Transportation, Intel® Corporation

Wai Yeong Yau  
Business Development and Product Marketing,  
Smart Cities and Transportation, Intel® Corporation

## Contributors

Syamak Nazary  
Global Sales Director, Transportation

Jenny Wen  
Strategic Planner, Software & Advanced Technology Group

Satish Jadhav  
Product Marketing Engineer, Edge Marketing,  
Network Platforms Group

## Technical Advisors

Mandar Chincholkar  
Director, Edge Compute Customer Solutions, SmartEdge  
Division, Network Products Group, Intel® Corporation

Ming Lei  
Platform Solution Architect, Cities & Transportation

## Research Consultants

Bridge Partners  
Harbor Research  
ABI Research

## Executive Sponsor

Sameer Sharma  
Global General Manager, IoT, Intel® Corporation

“5G—especially when combined with AI, computer vision, and edge computing—unlocks unprecedented opportunities to fulfill the promise of Smart Cities and Intelligent Transportation.”

## Sameer Sharma

Global General Manager, IoT,  
Intel® Corporation

“The city of Turin...sees C-V2X services as fundamental to develop a sustainable and safe mobility for all the citizens, whatever kind of transport they use. In the future, Turin wants to continue the collaboration with 5GAA and offer its smart road infrastructure to further scale in live traffic...”

## Chiara Foglietta

Deputy Mayor for Mobility, Ecological and  
Digital Transition, Innovation, City of Turin, Italy





# Overview

Cities are always on the move, under construction, and evolving to meet the needs of their dynamic environments. Today's urban environments are under mounting pressure to improve public safety and transportation, provide higher quality and more sustainable services, promote local economic competitiveness, reduce costs, and address congestion and environmental issues. As cities and municipalities have turned to technology to improve the lifestyles of their citizens, advances in 5G, Internet of Things (IoT), edge computing, and AI (artificial intelligence) offer cities opportunities to enhance citizen experiences and services while building secure and sustainable urban environments designed to support a thriving economy. 5G provides the next wave of technological enhancements to improve the mobility and better the lives of citizens. In combination with other technologies, 5G is dramatically changing the way citizens live, work, and get around in cities.

5G sets new standards for fast performance in comparison to their predecessors. For example, the worldwide median download speed over 5G was 954% faster than that over 4G during Q3 2020. Median upload speed over 5G was 311% faster than that over 4G.<sup>1</sup>

5G supports the advancement of infrastructure in unprecedented locations, on land, on the water, and on the rails. AI compute at the edge makes possible real-time solutions ranging from mass transit and intelligent traffic management, to vehicle to everything (V2X), streetlights, parking meters, and sewer lines. IoT sensors can monitor everything from air quality to energy use, security, traffic patterns, and city transit usage. With 5G, Intelligent

Transportation and Smart Cities can achieve massive device connectivity, higher data rates, reduced latency, higher system capacity, and lower total cost of ownership.

5G enhances the value of multiaccess edge computing (MEC) architecture. MEC provides real-time cloud computing and IT service environment at the edge, complete with processing and data storage. MEC and 5G allow developers to build applications with lower latency, high performance, and greater reliability. These technologies can positively impact a wide range of use cases involving automated mass transit, smart parking, crowd management, emergency response, environmental monitoring, and many more.

Communications service providers (CoSPs) are poised to deliver on private and hybrid network demand—optimizing, virtualizing, and monetizing their network resources while providing their customers and other organizations with access to rapid data insights via IoT services and applications. With 5G, CoSPs can facilitate more infrastructure as a service, offering real-time computing/AI at the edge and creating new business models for developers.

5G offers city and transportation leaders the opportunity to modernize their core technology infrastructure and establish a new and better foundation to meet today's growing demands for urban innovation. From network to cloud to device, Intel is accelerating the full potential of 5G with technologies that can shape the network transformation. With proven leadership in wireless, computing, and the cloud technologies, Intel is powering a transformation in how cities and transportation function.

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<sup>1</sup> [Massive Expansions and Huge Improvements in Speed: The Worldwide Growth of 5G in 2020](#), GSMA, December 2020



# Challenges

## Challenges for Cities and Transportation

A revolutionary technology like 5G can improve so many areas of transportation and urban life, but there are many areas to consider when city and transportation leaders invest in this new infrastructure.

### Public Safety and Security

Enhancing and assisting law enforcement and citizen safety to build trust with citizens. City leaders want to know that any new technologies they implement and the resulting data they collect will help improve the safety of citizens, facilitate greater citizen mobility, and improve the overall community.

### Economic Growth and Stability

Making the right investments in services and technology to promote a competitive city for economic development and growth.

### Data Management

Exploring how to provide secure access to and manage growing volumes of data from connected vehicles, smart spaces, smart mobility, and other essential use cases.

### Transportation Management

Choosing the right priorities as the increasing number of vehicles on roadways along with aging or insufficient infrastructure create traffic congestion, plus questions of infrastructure management and road safety.

### Mobility

Ensuring that improved mobility provides citizens with access to opportunities in jobs and education and improved quality of life.

### Supporting Civic Engagement

Working with citizens to provide services requests, city information, community networks, and better engagement with city leaders.

### Scaling Physical Infrastructure

Aligning on the priorities for physical infrastructure where digital services can provide for greater efficiencies in services, cost-effective scale, and higher usage rates at the right time and place. Legacy infrastructure and traditional hardware are typically outdated and don't support the evolving needs of Smart City applications that employ visual computing and AI capabilities.

### Environmental Stewardship

Evaluating environmental impact. Ensuring alignment with international, national, and regional goals to improve air, water, green space, recycling, and waste management outcomes.



## Key considerations for success with 5G

Implementing smart cities and transportation systems requires overcoming IoT complexity and legacy infrastructure.

**Convergence of technologies:** Successful implementation requires 5G compute and networking nodes capable of hosting 5G connectivity plus communications and software that enable a range of smart infrastructure use cases. 5G supports previously unsupported workloads at the edge that require low latency and/or high compute for near-real-time workload scenarios.

**Baseline requirements:** Robust real-time processing that creates low latency; versatility.

**Moving beyond legacy limitations:** A cost consideration that may also have an impact on speed of deployment is that traditional hardware solutions may not support the evolving needs of Smart City and Intelligent Transportation applications using visual computing and AI capabilities. From a software standpoint, Kubernetes architecture—an open source system for containerized applications—helps streamline edge deployments and provides a cloud-native foundation.

**Bandwidth demands:** The explosion of data generated from IoT devices significantly increases the bandwidth consumption and costs required to transfer all that data to public cloud datacenters.

**Data security and compliance:** Valuable data is traversing multiple networks until it is finally stored in the cloud, potentially creating data security and data sovereignty issues to be addressed.

**Deployment complexity:** Building, testing, and deploying solutions on-premises and at the network edge can be complex.

# Opportunities

## Opportunities for 5G to Help Cities and Transportation Address Challenges

Managing the unpredictability of new technology may pose a challenge for city and transportation leaders. As cities grow, resources could spread thin, forcing leaders to carefully manage the challenges of complexity.

Urban areas are the center for economic and societal change. In the next 15 years, cities will add 1.5 billion residents. 5G will connect them to services, mobility, and each other. The faster and more powerful connectivity of 5G makes possible services that can improve safety, efficiency, health, security. 5G can help cities support new business models, optimize resources, and gain new efficiencies that balance the cost of upgrading. For example, it can improve the management of vehicle traffic and and EV charging network utilization,

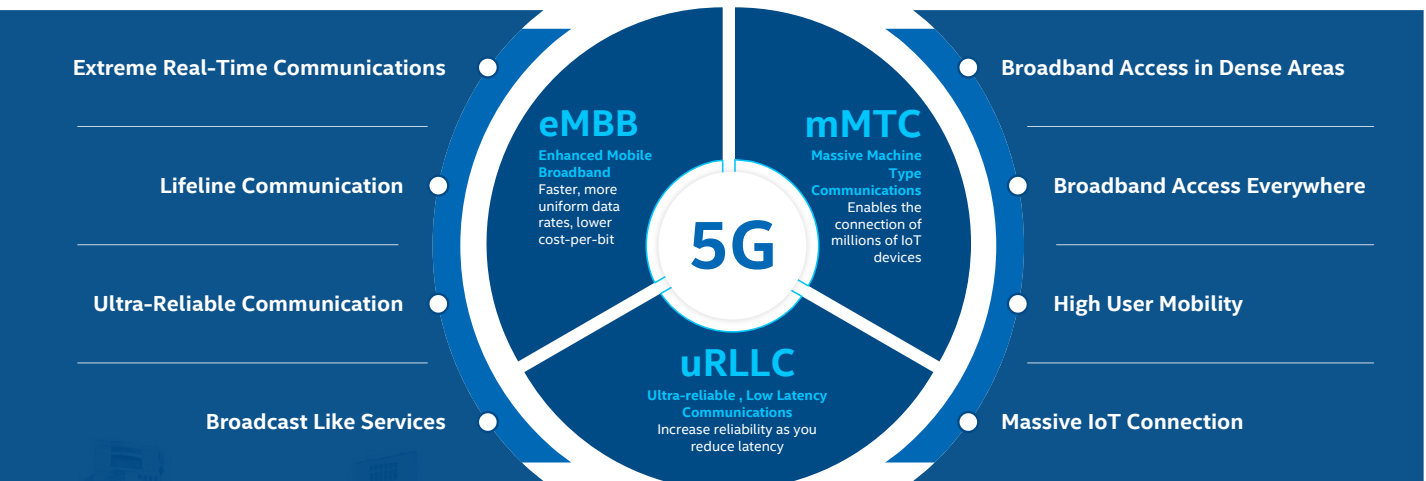
producing savings through reductions in energy usage, traffic congestion, and fuel costs. This means that commute times could shrink, public safety could improve, and significant smart grid efficiencies could be realized.

Intel continues to pave the way for disruptive new technologies by driving standards, pursuing spectrum advocacy, prototyping, trialing, and engaging with the 5G ecosystem. To that end, Intel participates in more than 300 standards groups worldwide<sup>2</sup>, holding leading positions in the ITU, 3GPP, IEEE, and 5GAA, among others. Intel has also provided proprietary research, reference designs, and insights from dozens of trials—all of which have helped make 5G a reality.

<sup>2</sup> [What is 5G Technology?](#), Intel

## Understanding 5G Capabilities and Components

Intended to replace 4G, 5G is a mobile communications standard enabling a new kind of network that **is designed to connect virtually everyone and everything together** including machines, objects, and devices. **5G enables innovations including network slicing, dynamic spectrum access, virtualized open radio access, and small cell platforms** – innovations that require wireless compute capabilities for smart devices at the edge, like MEC.





## Customer Showcase

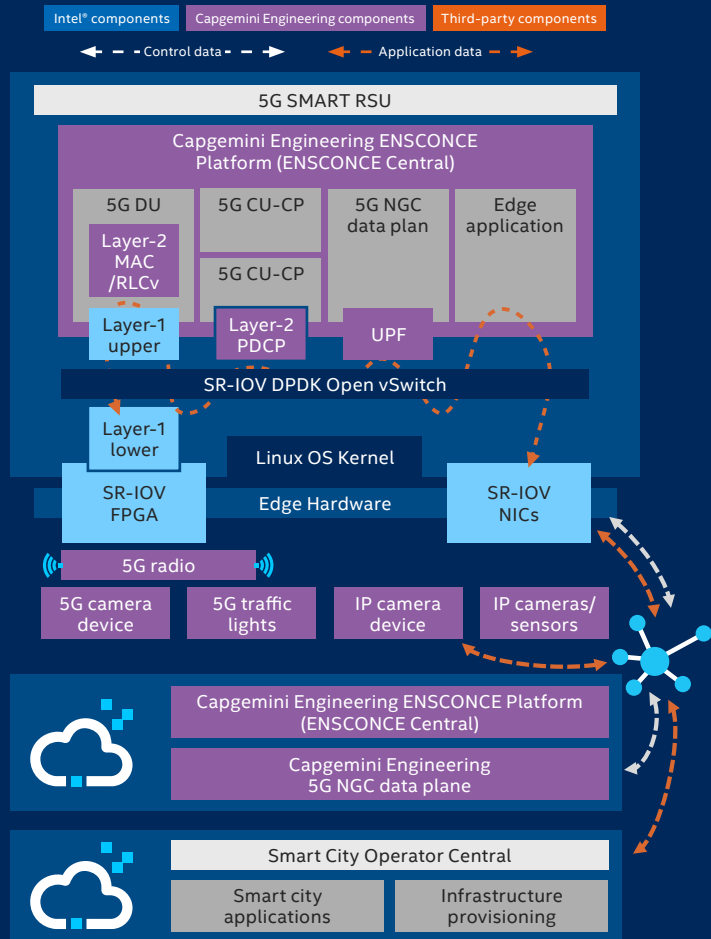
# Intel and Capgemini Smart 5G RSU (Roadside Unit) Solution for Intelligent Transportation

Designed in conjunction with application developers, enterprises, operators, and device makers, the Smart RSU solution makes possible intelligent transportation applications like traffic management, EV charging, smart lighting, and connected vehicle services. By placing computing at the network edge, the Smart RSU solution reduces network latency and processing times. The Smart RSU solution incorporates Capgemini Engineering's ENSCONCE multiaccess edge computing (MEC) platform. ENSCONCE implements Intel® Smart Edge Open technology, which brings intelligence to the network edge while hosting 5G network capabilities and microservices.

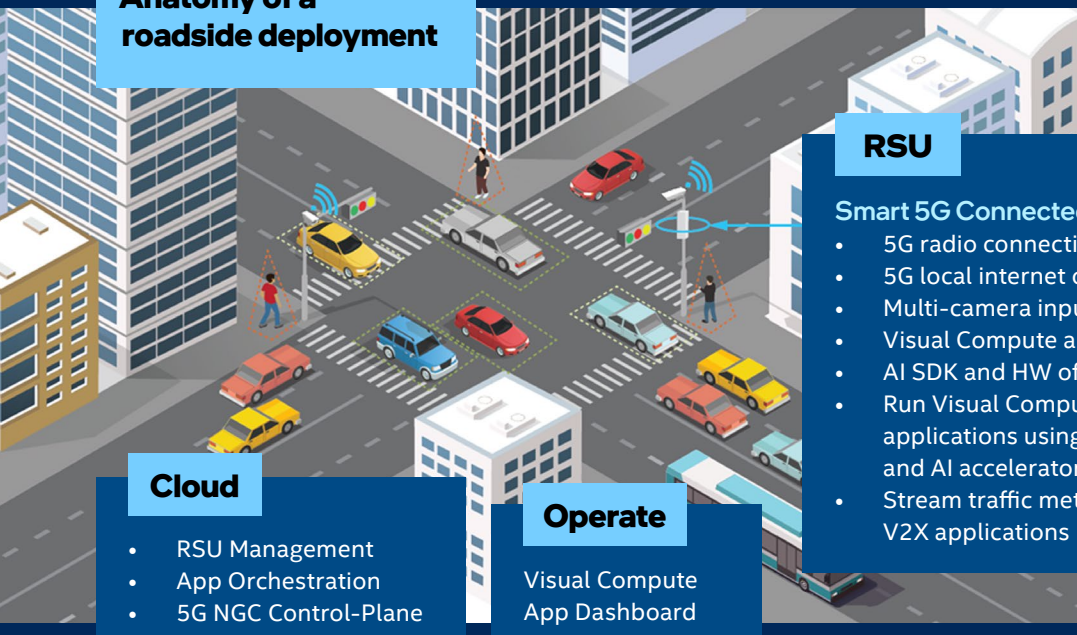
### Key features and benefits:

- Platform elements, including Intel® Smart Edge Open technology and Capgemini Engineering ENSCONCE MEC Platform work in concert to maximize 5G network, cloud, and computing performance.
- By integrating technologies like Intel® Smart Edge Open and Intel® Distribution of OpenVINO™ toolkit into the ENSCONCE platform, Capgemini Engineering has enhanced the capabilities of its edge computing solution with converged edge use cases.

## 5G Smart RSU journey of a packet



### Anatomy of a roadside deployment



### RSU

#### Smart 5G Connected Platform

- 5G radio connectivity
- 5G local internet offload
- Multi-camera input
- Visual Compute app
- AI SDK and HW offload
- Run Visual Compute Inference applications using Intel OpenVINO and AI accelerators
- Stream traffic meta-data for V2X applications

### Cloud

- RSU Management
- App Orchestration
- 5G NGC Control-Plane

### Operate

- Visual Compute App Dashboard

# Use Cases

5G enables a diverse set of use cases and applications. With the data collection and processing power to more efficiently monitor and control city resources and transportation systems, 5G helps cities and transportation leaders provide improved services, especially in smart cities and intelligent transportation.

## Intelligent Transportation

### Smart Mobility

#### Airports, Bus, & Train Terminals

5G technology can provide a better customer experience for passengers and more profitable engagement opportunities for stakeholders. Improvements brought by 5G can include better passenger information, more efficient passenger movement throughout the terminal, and advances in security protocols and screening.

#### Municipal Fleets & Buses

Tracking vehicle and passenger movements in real time with the support of 5G facilitates better response to delays and unexpected events (such as emergency vehicles or public demonstrations).

#### Rail

5G can help city leaders improve passenger flow, safety, and comfort within the terminal, as well as manage rail traffic, information access, and even driverless mass transit systems.

### Road Infrastructure

#### V2X

New Vehicle-to-Infrastructure (V2X) standards, using cellular technology supported by 5G, supports advanced connectivity between vehicles, infrastructure, and other road users to promote safe mobility.

#### Traffic & Parking Systems

Underpinned by the speed and data flexibility of 5G, cities can completely transform their traffic and parking systems. By efficiently guiding drivers to vacant spaces, smart parking solutions can help reduce traffic congestion.

#### Connected Corridors

5G-enabled smart roadways can create connected corridors for the next generation of highway travel. In mixed speed environments with a combination of autonomous, connected, and conventional vehicles, 5G and intelligent edge computing can facilitate safer interactions and reduce travel times.

### Digital Maritime

#### Marine

5G and high-performance networks enable mission-critical apps, agility at the edge and cloud, and faster, better-informed decision making. For example, 5G-based cargo monitoring systems power cold chain management and maritime transport applications support navigation and route optimization systems.

#### Ports

5G-based access controls and security systems help protect valuable workers, cargo, and data. Inventory and transport equipment monitor and move baggage, packages, and other materials.

## Smart Spaces

#### Entertainment Venues

As stadiums, movie theaters, casinos and more venues re-open after the pandemic, 5G technology can help enhance crowd management, enforce health protocols, and generate timely information that keeps attendees, participants, and staff members safe.

#### Public Spaces

5G empowers city managers to keep citizens safe and secure, by enabling situational awareness along with speedier responses to unanticipated events.

#### Commercial and Institutional Campuses

Ensuring the safety of workers, customers, and visitors in workplaces requires new technologies that help control access and enforce safety protocols, making in-person interactions safer and more secure. 5G can help improve operational efficiencies and instill confidence in health and safety.



## Government & Agencies

### Public Safety

#### Incident Detection

In a Smart City with 5G, connected devices, especially low-latency video cameras, can provide information that empowers first responders and public safety officials to respond more quickly.

#### First Responder and Emergency Management

In a 5G Smart City, when an emergency is detected, a system can trigger several emergency response actions, including faster deployment of first responders.

#### Sensor Monitoring

Sensor networks continually monitor the state or behavior of a particular environment. 5G-based sensors can detect anomalies, potential hazards, malfunctions, and more. This can aid in improving safety by automatically triggering a specified response, such as a machine's emergency stop, in case of the detection of a critical problem.

#### Crowd Management

Smart Cities can monitor video feeds for enforcing restricted zones at various locations across a city and analyzing activity to anticipate and manage potential trouble spots.

### Environmental and Infrastructure Monitoring

#### Building Automation

Building automation refers to the management of equipment in buildings such as heating, cooling, ventilation, and lighting systems. Automation of such systems helps reduce energy consumption, enhances the comfort level of people inside the building and improves failure management and accelerates the ability to react to emergency situations.

#### Environmental Monitoring

With 5G, Smart Cities can support more efficient recycling, waste management, air-quality monitoring, and water-quality assurance.

#### Electrical Power Distribution

New sensors and actuators are being deployed to efficiently monitor and control the volatile conditions of the electrical grid, requiring real-time information exchange. The smart grid enhances insight into the grid as a power network and a system of systems. Enhanced insight improves controllability and predictability.

## Customer Story Showcase: Utah Inland Port Authority Builds Private 5G Network

A new private LTE/5G network is going to build greater inland visibility and reduce pressure on logistics in ports and terminals. [The Utah Inland Port Authority \(UIPA\) is partnering with QuayChain Technologies to operate the world's first private network to be used solely for the supply chain.](#) The network, currently under development, aims to leverage the benefits of lower latency and enhanced connectivity to capture increased levels of data in real-time and provide a stronger picture of end-to-end logistics.

The UIPA, which serves some of the continent's busiest ports (such as Los Angeles, Long Beach, and Oakland) is a lynchpin for transferring cargo in and out of inland markets. A private LTE/5G network, provided by QuayChain, working with infrastructure provider Nokia, will provide autonomy with the network itself. This private network centralizes focus on just the supply chain actors without having to balance different subscriber needs and priorities.

IoT-based sensors and gauges monitoring chassis and rail movements will benefit from the private network's improved connectivity and resiliency and provide a real-time picture of cargo flows.

Logistics operators within the port's ecosystem will be able to see every movement of cargo flow from vessel to inland markets. UIPA will be able to make smarter day-to-day decisions for customers using the port and improve practical decisions such as where and when to allow trucks to idle. Utah has both challenging terrain and an extreme climate. Together, these create a dynamic and challenging environment for autonomous vehicles and electric-powered equipment.

The 5G network will bring more fluidity for rail and trucking partners in Utah and better preparation for seasonal cargo surges. With the new network set to be deployed to every facility in the logistics chain, improved connectivity will provide potential for further automation and technological advances.



# Technology Summary

Visionary city and transportation leaders can simplify the path to safer, more efficient, and more connected cities and safer, more effective modern transportation with an end-to-end 5G solution enabled edge compute solution based on Intel technology. Intel powers every segment of the smart, connected world, from the device to the network to the cloud. Intel technologies and the vast ecosystem of partners and solutions create a more vibrant, extensible, and sustainable way for leaders to implement intelligent data strategies. Additionally, Intel helps protect connected systems from the inside out with a foundation of security technologies designed to protect the entire device stack against a wide range of attacks. 5G systems facilitate high-capacity, high-reliability, and low-latency use cases, with some applications requiring greater levels of privacy when storing data locally. Simultaneously, edge compute capabilities support managing more compute and intelligence closer to the endpoint devices that are both generating and consuming data at the edge. Hence industry leaders are looking at both increasing the network's capacity and placing more compute and real-time analytics closer to the edge, where the data is collected and consumed. Moreover, there is a strong demand for efficient hardware accelerators to support AI solutions in an energy-efficient and real-time manner.

## From cloud to network edge

Intel-powered solutions help city leaders simplify networking complexity and take advantage of edge-to-cloud computing. Intel-based edge computing nodes and multi-access edge computing (MEC) edge servers leverage the power of 5G with the help of Intel® Smart Edge Open technology to improve real-time public safety and traffic data at the edge while also advancing connectivity and transmission to and from wireless networks. The key wireless connectivity technologies are cellular and Wi-Fi. In cellular, we have side link (C-V2X, NR V2X) and direct link (UU). Regardless of the technique, they must work together to provide low latency, high capacity, and high reliability connection to all users. [Learn more at Intel® Smart Edge Open.](#)

MEC architecture provides real-time cloud computing and an IT service environment at the edge. MEC processes and stores data at the network and on-premise edge, dramatically lowering latency, enabling developers to innovate and build applications with high performance, and better reliability

## Private Networks

High-capacity, low-latency private network solutions can enhance coverage, enable data control, and improve costs for cities deploying 5G. Intel's complete set of network technology solutions—from silicon to accelerators, software, and reference solutions all with strong ecosystem partnerships—is best suited to meet the demands of private networks now and in the future. Intel works closely with city leaders to define the requirements of solutions from the client to the edge and the cloud, providing optimized placement of network functions (including SD-WAN, RAN etc) and workloads such as security AI, analytics, and others. Versatile deployment options provide flexibility and agility while helping to provide TCO savings driving innovation for smart cities.

## Edge Compute

Enhanced for IoT and embedded use cases, Intel processors come in a range of options for compute performance and power consumption, enabling cutting edge and performant audio and visual compute capabilities for intelligent cameras and sensors attached to buildings, at roadside, and within vehicles. Intel offers a wide array of options for embedded and edge computing, from high-efficiency Intel® Movidius™ VPUs to low-power Enhanced for IoT Intel Atom® processors, high-performance Intel® Core™ processors, and Intel® Xeon® Scalable processors. [Learn more about edge computing.](#)

## vRAN (Virtualized Radio Access Networks)

Intel's FlexRAN™ reference architecture enables communications service providers to build and deploy highly optimized, feature rich, 4G and 5G scalable cloud native RAN solutions on Intel® architecture. FlexRAN software targets broad use cases from indoor to cloud to distributed RAN and Rural areas. Intel has a broad ecosystem of FlexRAN partners who can help network operators architect their networks to roll out 5G at greater scale, take advantage of edge computing and technology inflections such as AI. It also allows operators to reduce time to market by adopting an optimized hardware and software platform with Layer 1-3 software already integrated. Furthermore, Intel offers a full suite of optimized silicon, accelerators, Ethernet devices and pre-integrated solutions with ecosystem partners enable the global scale of vRAN.

Diverse HW Portfolio to Build for the Edge	Powerful Developer Tools & SW Reference Solutions		Meet Unique Use Cases with a Vast Ecosystem
<b>Hardware Platforms</b> 	<b>Development Tools</b> 	<b>Intel® Edge Software Hub</b> 	<b>Intel Select Solutions</b> 
<b>Commercially Available Solutions</b> 	<b>Reference and Production Software</b> 		
<b>Reference Designs</b> 			

## 5G Industry Partnerships

Intel's strategic differentiation stems from a diverse and flexible portfolio of hardware and software products that can serve infrastructure and devices from the Network Edge to IoT Devices that have varying degrees of edge compute and power consumption requirements.

Dedicated accelerators such as Intel® ACC-100, help unleash the speed of 5G. They support higher channel capacity and easier deployment of edge-based services and applications. vRAN helps to deliver low-latency services with the flexibility to increase or decrease capacity based on the volume of real-time traffic and demand on the network. [Learn more about Intel® vRAN Dedicated Accelerator ACC100.](#)

Intel's E810 family of Ethernet controllers provides smart and customizable capabilities with high capacity programmable Accelerators and Ethernet connectivity that can accelerate infrastructure applications running on the host (Up to 100GbE for bandwidth-intensive workloads). FPGA (field-programmable gate array)-based SmartNICs help transform wireless and wireline broadband access networks by providing increased visibility into network traffic at the edge, accelerating hardware performance and improving scalability in a cost-effective way.

### AI Accelerators

Intel accelerators and appliances built on Intel® Movidius™ Vision Processing Units (VPUs) and Intel® FPGAs can add high-performance AI and vision technology from edge devices—smart cameras, autonomous controls—to on-premises servers and AI appliances. The latest Intel® CPUs include integrated acceleration so you can run AI workloads on edge devices and servers. Processors with Intel® Iris® Xe integrated GPUs can put even more inference-processing power into low-powered edge devices.

### Service Orchestration & Security

Keeping ITS software up to date is simplified with time-saving tools like remote device management and automated software deployment to devices at the edge. The SmartEdge platform provides capabilities for orchestrating edge clusters, manageability tools for deploying edge nodes and managing the lifecycle of HW and SW elements deployed in a highly distributed edge environment.

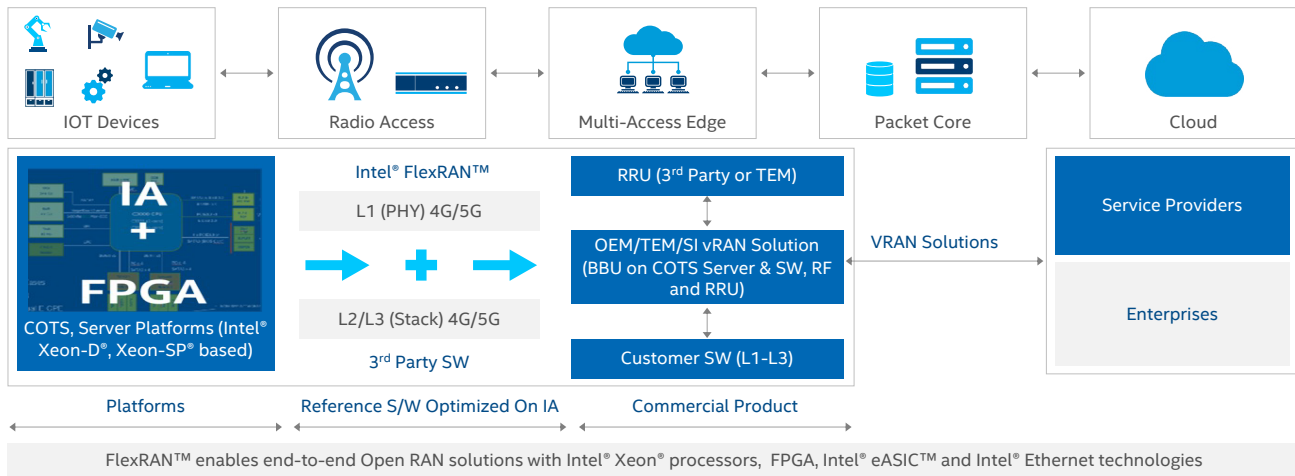
Intel processors feature multiple hardware-based security measures that help protect public and private data with hardware-based security technologies. Intel hardware includes chain of trust technologies for platform integrity: trusted execution environments that isolate applications. Dedicated cryptographic accelerators handle complex security calculations without taxing system resources. Technologies that were formerly separate are converging into unified systems providing more insight to drive efficiency. Intel hardware and software have the performance and flexibility city leaders need to manage these ever-growing demands and workloads.



**Developer Tools**  
**Intel® Edge Software Hub**

Intel makes it simple to optimize edge solutions, including computer vision and deep learning applications for Intel architecture. You can experiment, test, and create using the IoT Developer Program. Choose your architecture type, and then select from Intel, third-party, or open source software. Whether building from scratch or customizing a ready-made reference implementation, we offer helpful resources to accelerate your development. Intel® Smart Edge Open Experience Kits provide blueprint as reference for on-premises 5G deployment with edge services. For example, the Private Wireless Experience Kit (PWEK) accelerates private 5G deployment with Intel Edge platforms. Combining Intel cloud native technologies, wireless networking, and high-performance compute, the PWEK delivers AI, video, and other services with optimized performance on Intel edge platforms. [Learn more about the PWEK.](#)

**Bridging the Gap Between 5G and Intel Solution Architecture with FlexRAN™**



[Learn more about the IoT Developer Program](#)







## Standards

Looking to the future of IoT, cybersecurity technology, autonomous systems, AI, connectivity, and cloud computing, standards are the common tool to bring innovations to markets around the world. Intel contributes to standards which address global environmental issues and best practices for corporate governance and business operations as well as product safety. Intel participates in hundreds of standards bodies and industry groups worldwide and has played a significant role in bringing about globally adopted ubiquitous standards, including Ethernet, USB, and Wi-Fi.

## Technology Research and Contributions to 5GAA and ETSI V2X Standards

C-V2X is a cellular standards-based technology supported by 5G that will enable advanced connectivity between vehicles, infrastructure, and other road users to promote safe mobility. Vehicle-to-Vehicle and Vehicle-to-Infrastructure (V2X) standards will enable the future of Intelligent Transportation Systems (ITS). Intel has been an active member of technical bodies, contributing to the definition of ITS use cases and specifications.

European Telecommunications Standardization Institute (ETSI) Multi-access Edge Computing (MEC), standardized by ETSI ISG MEC, enables an open market and new business models. ETSI is also standardizing CPS for connected vehicles and roadside infrastructure.

## Vulnerable Road User (VRU) Awareness Basic Service

According to World Health Organization, about 1.3 million people die each year in road traffic crashes, out of which more than half of the victims are low-mobility, high-physical-impact-VRUs such as pedestrians, bicyclists, and motorcyclists. We at Intel envision that smart roadside infrastructure, such as roadside units (RSUs) deployed within the smart intersections can play a crucial role in improving VRU safety.

## Technology Research Outreach

Intel Labs works with and sponsors and leading researchers around the world. That includes prominent university science and technology centers, The National Science Foundation, and the Semiconductor Research Corporation. Together we are doing research that is transforming how machines think, learn, and adapt, and how we compute, secure, and communicate the data that will help fuel our digital economy.

Intel is participating in the joint effort of experts from many different technical disciplines spanning research, development, operations, and applications. The result is a comprehensive discussion and guide that also shows how multi-dimensional complexity challenges can be tackled, bringing together expertise from multiple backgrounds united by a common goal: automating and optimizing 5G networks to capitalize on edge computing advances that serve future customer requirements and applications. [We are eager that this white paper will help the ecosystem achieve a consensus around the future of 5G and the edge technology roadmap, working closer to realize the vision, and bring a better automated, intelligent world together.](#)

For decades, Intel has been at the forefront of technology research, innovation, and development for compute, storage, and networking that power many of the world's data centers, communications infrastructure, and personal computing. Intel is continuing that legacy with the intent to continue to lead technologies and platforms for assisted driving, 5G communications infrastructure, and AI. At every step, Intel takes a deeply integrated approach with technology to provide a robust set of compatible solutions, platforms, products, technology innovations, and architectures to complement one of the world's most dynamic set of technology ecosystem partners.



## Digital Twin Virtual Environment Orchestration and On-Demand Services

Recent breakthroughs in multimodal sensing and real-time environmental perception technologies have led to accurate semantic and kinematic parameter estimation of objects in the sensors' field of view, which can be leveraged at the roadside infrastructure. The latest sensors include vision, LiDAR (light detection and ranging), radar plus connectivity, and more. For example, stereo image sensing technologies can calculate depth and enable devices to see, interact with, and learn from their environment. By using edge computing capabilities, the infrastructure may create a digital twin model of its surrounding environment where each actor in the virtual environment is assigned a temporary unique tracking identifier, and their kinematic parameters are continuously tracked.

Such a virtual environment at the edge can enable the roadside infrastructure to provide safety and on-demand commercial services to vehicles in need of additional sensor data/analytics or augmentation, or other road users (such as pedestrians, bicyclists, etc.). For example, the environmental perception in the digital twin can detect the availability of parking spaces in real-time, and such live information can be used to disseminate parking information and reservation services to road users.

Towards this end, three service verticals supported at Roadside Units (RSUs) can be envisioned: communication services, edge services, and digital twins.

## Customer Story Showcase: City of Turin 5G Connected Car

The City of Turin (Italy) hosted a live trial of new driver and pedestrian safety technology allowing near-real-time notification of roadway hazards through 5G-Edge networks in late 2021. [This trial was one of a series conducted internationally by a historic public-private collaboration over the next few years, organized by the 5G Automotive Association \(5GAA\) and eight member companies representing leading technology companies.](#) Companies partnering with the City of Turin and 5GAA for the historic public-private collaboration include Telecom Italia (TIM), Telefonica, BT/EE, Intel, and Capgemini.

The connected car concept uses high-speed and Edge computing technology, along with the Internet of Things (IoT), to communicate with car sensors and pedestrian smartphones. A user-authorized mobile app notifies drivers about traffic hazards, like accidents and road construction to improve pedestrian and in-vehicle driver safety and efficient navigation.

The live international trial attempted to solve one of the more technical challenges of making the connected car a reality. Successful implementation includes elements of automation, intelligent infrastructure, cybersecurity, and workload controls. The 5G networks underpinning the concept are managed by communication service providers (CoSPs) according to geography, each with different edge solutions that must be able to communicate without interruption of the vehicle-to-everything (V2X) applications as drivers cross borders. Roaming services—the ability to make a call regardless of the network—is one early success of multi-mobile network operators (MNO). The trial demonstrates how

the car manufacturers, MNOs and technology providers come together to help overcome the challenge of vehicles moving from one network boundary to another or inter-MNO handover of MEC service.

TIM, BT/EE, and Telefonica host Capgemini's ENSCONCE MEC platform, built upon the Intel® Smart Edge Open toolkit, the Intel® Distribution of OpenVINO™ toolkit, and Intel hardware to enable connected car use cases at the Edge on 2nd Gen Intel® Xeon® Scalable processor equipped Cisco Servers. Intel® Smart Edge Open (formerly known as OpenNESS) is a royalty-free edge computing software toolkit for building optimized and performant edge platforms.

*“As TIM, we are honored to be hosting in Turin such a challenging trial by leveraging our Innovation Lab competencies and our pre-commercial instances of Edge Cloud. The federation model implemented with our partners enables a ‘continuum’ between Edge Cloud instances allowing players from the automotive industry and beyond to benefit from a seamless cloud experience across country boundaries.”*

**Daniele Franceschini**, VP for Innovation Standard and Portfolio, Telecom Italia

The trial showed the value of a large ecosystem that encompasses both public and private sectors. Such collaborations can help develop not only the technology but also the 5G business applications that drive the digital transformation for smart cities of the future.



# Solution Spotlights

Intel supports innovation and collaboration with partners in several ways. Intel's Go-to-Market support includes Engineering/Design-In collaboration and breakthrough technical advancements through the network of Intel Labs research. Support also includes Engineering/Design collaboration with the network of Intel Labs research. Intel's Go-to-Market support includes sales enablement (collateral, demand generation); sales pipeline development for partner solutions; marketing and thought leadership; policy and standards contribution and influence; transportation grants support. For more information on partnerships, view the [Intel® IoT Market Ready Solution](#) and [Intel® RFP Ready Kits](#).

## 5GAA Trial in Turin, Italy

The City of Turin (Italy) hosted a live trial of new driver and pedestrian safety technology allowing near-real-time notification of roadway hazards through 5G-Edge networks in late 2021. Companies partnering with the City of Turin and 5G Automotive Association (5GAA) for the historic public-private collaboration include Telecom Italia (TIM), Telefonica, BT/EE, Intel, and Capgemini.

For more information: [Customer showcase](#)

## Capgemini 5G RSU (Roadside Unit)

Designed in conjunction with application developers, enterprises, operators, and device makers, the Smart RSU solution makes possible intelligent transportation applications like traffic management, EV charging, smart lighting, and connected vehicle services. By placing computing at the network edge, the Smart RSU solution reduces network latency and processing times. Please see customer showcase.

For more information: [Customer showcase](#)

## Lenovo and Cellnex Telecom Mobility Lab

Europe's largest provider of wireless communications, Cellnex Telecom has created the Cellnex Mobility Lab to develop new, sustainable, connected, and autonomous mobility solutions related to 5G for vehicles, traffic management, and smart road infrastructure. Based in Castelloli, near Barcelona, Spain, Cellnex Mobility Lab is the result of the digital transformation of Circuit Parcour Castelloli into an innovative technological center.

The Mobility Lab's 5G-based solutions are an innovative area to test and develop new technology and services advancing connectivity, especially in rural environments. Self-sustaining Green Edge sites are powered by renewable energy generated onsite, and enabled by technologies from Lenovo, NearbyComputing and Intel.

[Learn more](#)

## QuayChain Technologies

A new private LTE/5G network is going to build greater inland visibility and reduce pressure on logistics in ports and terminals. The Utah Inland Port Authority (UIPA) is partnering with QuayChain Technologies to operate the world's first private network to be used solely for the supply chain.

For more information: [Customer showcase](#)

### SkyLab

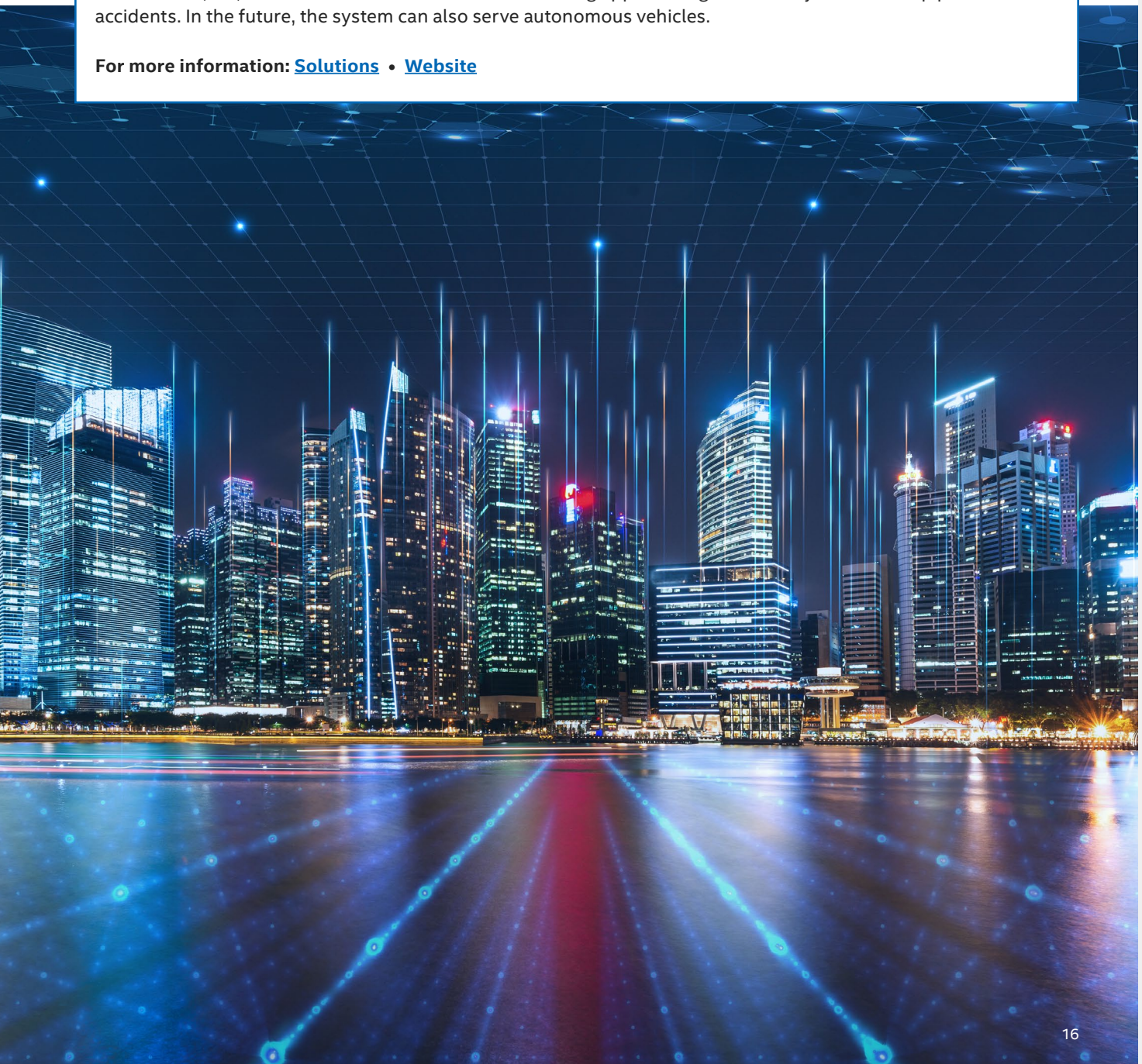
Cities have been investing in traffic management solutions for decades, but over time, disparate technologies and hardware have become costly and difficult to manage. By abstracting and consolidating resources into a converged solution, cities can simplify their infrastructure with low latency 5G connectivity and fast edge AI performance. The SkyLab Multi-access Edge Computing (MEC) platform helps city transportation agencies merge diverse workloads of network, camera sensors, and inference on a common infrastructure. It can be tailored to meet the specific needs of traffic management and has demonstrated success in use cases such as smart refueling stations, smart solar panel metering, and smart public rail systems.

For more information: [Solution](#) • [Website](#)

### TietoEVRY

As road traffic increases, so does the risk of traffic accidents, especially at intersections. The risk of injury and death is especially high for pedestrians. TietoEVRY has piloted a solution to improve pedestrian traffic safety. The solution can automatically detect when a pedestrian is planning to cross the street at an intersection. Advanced AI, IoT, and V2X communications enable alerting approaching cars. The system will help prevent accidents. In the future, the system can also serve autonomous vehicles.

For more information: [Solutions](#) • [Website](#)





# Next Steps

Strategic innovation and transformation are a continual journey. Many city leaders plan their 5G initiatives across three action areas to:

1. Transform data into new insights with intelligence from edge to cloud.
  2. Partner with Telecom Providers to deploy 5G
  3. Consolidate systems and use cases at the edge for greater efficiency and value. Initially, leaders should examine which services may have the most impactful outcomes.
- Leveraging experience working with many governments and infrastructure authorities worldwide, Intel is bringing together the right stakeholder organizations and companies to deliver building blocks that leaders can use to create and implement an appropriate plan for deploying 5G.

## Six steps to a 5G-enabled digital transformation journey



### Identify Stakeholders

Within the complex structure of your city, identify who the major stakeholders in any digital transformation project would be. Depending on the project, this can include government representatives, employee representatives, concessionaires, urban safety IT team, transportation security team, and passenger advocates.

### Assess Current State

Determine where your infrastructure system is now, measured in terms of the same key performance indicators you will use to quantify success. What works? What needs work? How can you improve satisfaction, security, safety, and success for all stakeholders?

### Create A Shared Vision

Establish your ultimate outcomes, expressed in terms of stakeholder benefits. The vision should not be expressed solely as technical achievements but also as experiential improvements that 5G technology can make possible. It is essential to build that vision with stakeholder

involvement to achieve better and more diverse suggestions, consensus, and commitment.

### Build Blueprints

Develop blueprints for the most important components of your network needs. Possibilities include master plans for:

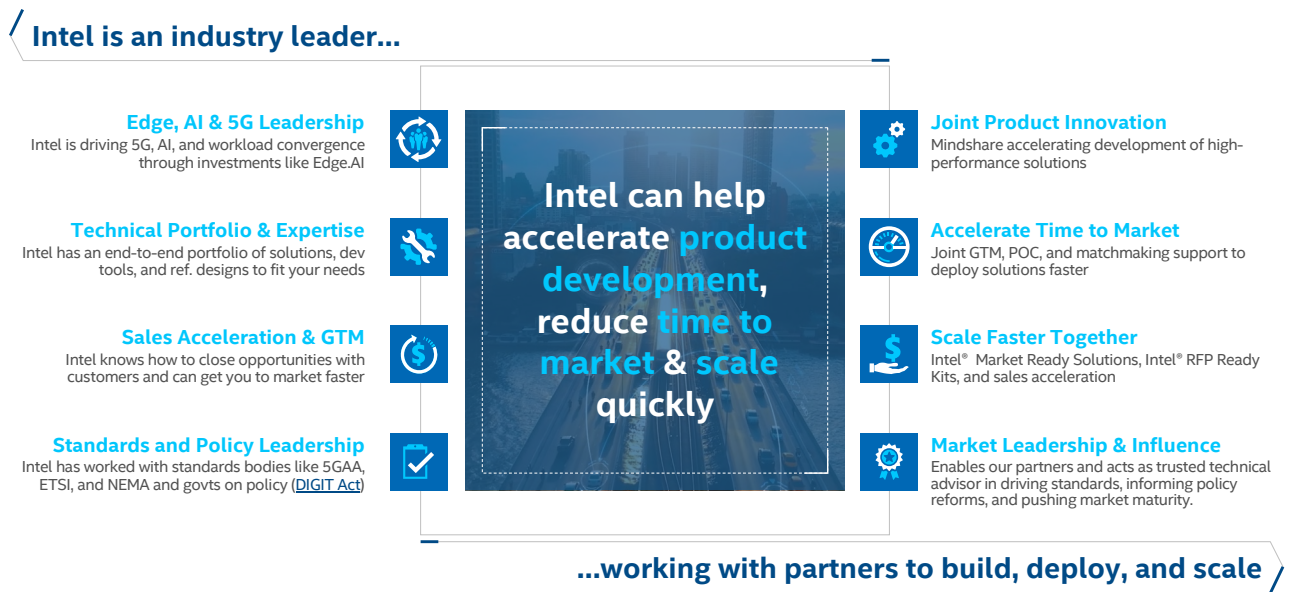
- Digital infrastructure (communications and computing resources)
- Data collection
- Use cases
- Business and commerce
- City services
- Mobility

### Mark Milestones

Identify waypoints at which you measure progress, share lessons learned, discuss course corrections, and strengthen stakeholder commitment to your shared vision. Select KPIs Decide on key performance indicators that quantify success and align with your vision.



## Extending the Breadth and Value of Software Solutions with Partners



### Explore Financing and Partnerships

Implementing a comprehensive Smart City and Intelligent Transportation vision and ITS upgrades require committed funding. It is a critical component that should be thoughtfully planned. Innovative funding and financing alternatives can accelerate Smart City and Intelligent Transportation projects. Many regions rely on tax revenue to support roads infrastructure projects. Although Vehicle Purchase Taxes (VPT) and fuel taxes are common worldwide, Vehicle Miles Travelled (VMT) taxes are replacing some fuel taxes to stabilize revenue as fuel prices experience volatility and decline. VMT taxes can also improve data acquisition, congestion, emissions, and value-added services (for example: safety alerts, real-time traffic management, routing assistance, and pay-as-you-drive insurance.)

Exploring multiple funding sources such as regional economic development; state and federal agency funding for transportation, public safety, environment; and private developer and industry partnerships are a few examples of broadening sources. Developing partnerships to embrace industry knowledge, best practices, key solutions, and technologies, can yield insights from planning to implementation. New business and monetization models are being explored by leaders throughout the world to support implementation of 5G.

Defining and executing a Smart City, Intelligent Transportation, and 5G strategy is neither straightforward nor without risks—but the benefits can be significant. Intel believes a successful city and transportation transformation requires certain key components: the right level of stakeholder participation, clear priorities, and methodical planning of technology infrastructure.

### Work Together for Success

As industry leader, Intel can collaborate with its partners to build deploy and scale 5G solutions that fit your transportation and city needs.

This is only a starting point for a transformative city and transportation journey. At Intel, we believe city leaders can successfully transform their cities by establishing clear priorities, encouraging active stakeholder participation, ensuring methodical technology infrastructure planning, while enabling the right policy and governance. **With our edge to core to cloud technology solutions with 5G connectivity and strong partner ecosystem, Intel can help bring your Smart City and Intelligent Transportation vision to life.**

# THINK BIG

...not just smarter, but **better** cities and transportation

# START SMALL

**Get going** with projects and opportunities

# MOVE FAST

Learn, adjust, **iterate**



intel.

# Additional Technology Resources

## Intel® Distribution of OpenVINO™ Toolkit

The Intel® Distribution of OpenVINO™ Toolkit optimizes deep learning models for Intel hardware and gives you a single development environment analytics, audio analytics, speech recognition, and natural language processing. Based on Convolutional Neural Networks (CNNs), the toolkit extends Computer Vision workloads across Intel hardware, maximizing performance. Infrastructure ecosystems can accelerate and deploy CNNs on Intel platforms with the Intel® Deep Learning Deployment Toolkit available in the OpenVINO™ toolkit and as a stand-alone download. Together with the new Intel® DevCloud for the Edge, OpenVINO™ addresses a key pain point for developers—allowing them to try, prototype and test AI solutions on a broad range of Intel processors before they buy hardware. Learn more about Intel® Distribution of the OpenVINO™ Toolkit.

## Intel® DevCloud for the Edge

The Intel® DevCloud for the Edge allows developers to actively prototype and experiment with AI workloads for computer vision on Intel hardware. Developers have full access to hardware platforms hosted in the Intel cloud environment, designed specifically for deep learning. Developers can test the performance of their models using the Intel® Distribution of OpenVINO™ Toolkit and combinations of CPUs, GPUs, VPUs such as the Intel® Neural Compute Stick 2 (NCS2) and FPGAs, such as the Intel® Arria® 10. The DevCloud contains a series of Jupyter\* notebook tutorials and examples preloaded with everything needed to quickly get started. This includes trained models, sample data, and executable code from the Intel® Distribution of OpenVINO™ Toolkit as well as other tools for deep learning. These notebooks are designed to help developers quickly learn how to implement deep learning applications to facilitate compelling, high-performance solutions. [Learn more about Intel® DevCloud for the Edge](#)

## Intel® Smart Edge/Smart Edge Open

Smart Edge Open drives the Intel vision of networks built on open, industry-standard edge computing. Built on OpenNESS, the Intel® Smart Edge offering is a multi-access edge (MEC) platform commercialized for market use cases for on-premises enterprise deployments that require low latency, private mobility, simplicity, and open architecture. Customers can stand up their own private network to enjoy security, service, and a broad set of network services. Networks can be configured in minutes and tailored to specific customer needs and applications. [Learn more](#)

Smart Edge is a cloud-native, scalable, and secure platform for multi-access edge computing (MEC). With Smart Edge, enterprises and communications service

providers can support cloud-like services closer to the user on the customer-premises or network edge. The Smart Edge platform is built to run on Intel technologies, such as high-performing Intel® Xeon® Scalable processors today and, going forward, Intel® Optane™ memory, Intel® FPGAs, and other accelerators. Smart Edge's software is also highly complementary with Intel's Smart Edge Open (Open Network Edge Services Software) project.

For enterprises and service providers, Smart Edge enables new opportunities and revenue streams while reducing the total cost of ownership for intelligent edge solutions. For example, the city of Tampere, Finland and TietoEVERY implemented a pilot solution to improve pedestrian safety by automatically detecting when a pedestrian is planning to cross the street. Advanced AI, IoT, and V2X communications make possible alerts for approaching cars—preventing accidents.

## Intel® oneAPI

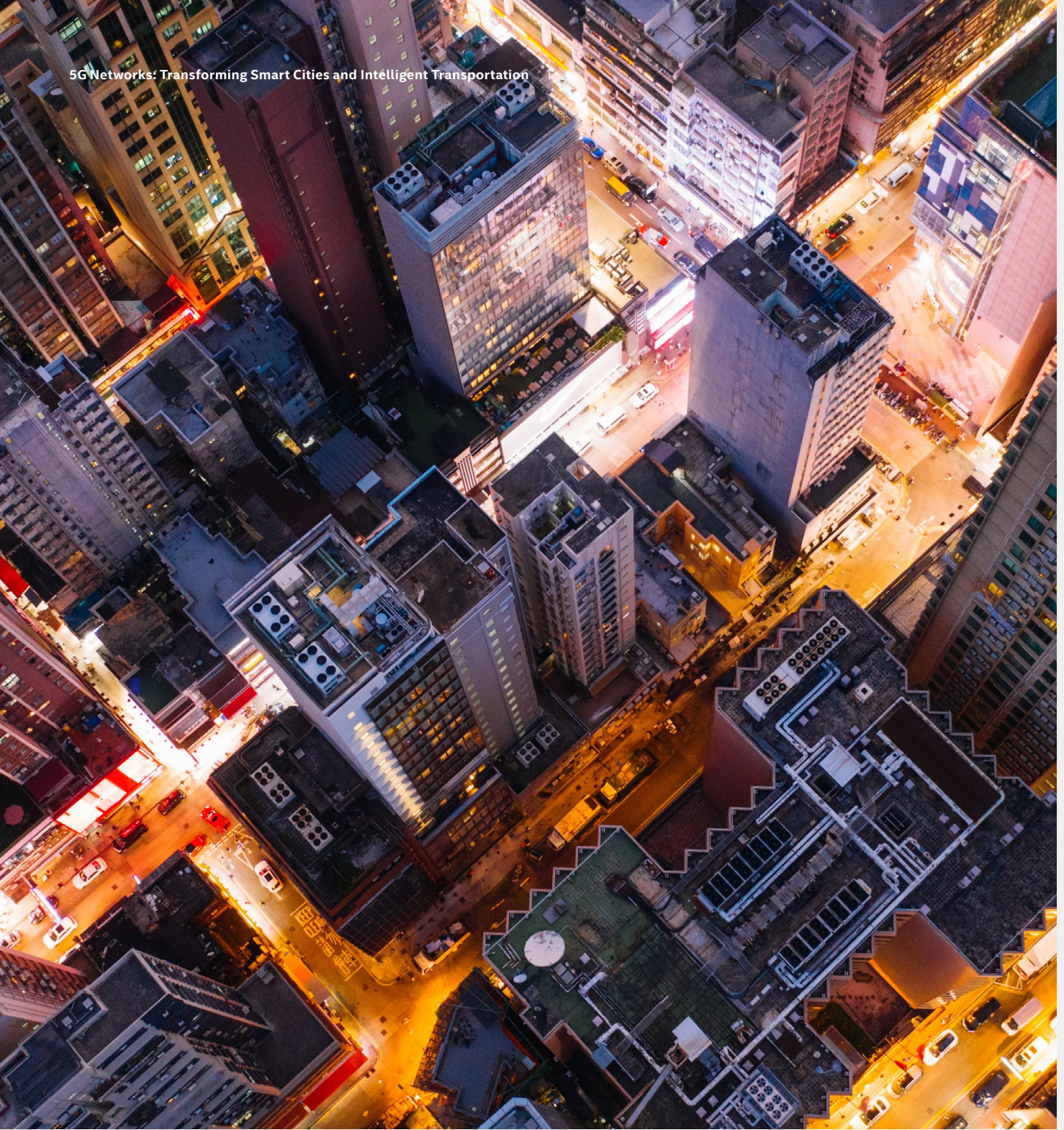
Intel® oneAPI products deliver the freedom to develop with a unified toolset and to deploy applications and solutions across CPU, GPU, and FPGA architectures. Data science and AI toolkits support machine learning and deep learning developers who primarily use Python\* and AI frameworks.

These toolkits are for performance-driven applications—HPC, IoT, advanced rendering, deep learning frameworks, and more—that are written in DPC++, C++, C, and Fortran languages. [Learn more](#)

## Open Visual Cloud

To help strengthen the ecosystem and provide ready access to the building blocks and pipelines for cost effective visual cloud innovations, Intel is providing reference pipeline recipes for Visual Cloud services using existing open source functions from Intel in an open source project called the [Open Visual Cloud](#). The Open Visual Cloud provides availability of high performance, high quality, open source, validated building blocks—across encode, decode, inference, and rendering—as well as reference pipelines that support visual cloud workloads such as traffic management. The goal is to minimize barriers to innovation for quickly and easily creating and monetizing Visual Cloud services. Support for familiar industry standard frameworks leverage the larger open-source community and include media (FFMPEG and GStreamer), AI (TensorFlow\*, Caffe\*, MXNet\*, ONNX\*, Kaldi\*), and graphics (OpenGL, DirectX). \*, ONNX\*, Kaldi\*), and graphics (OpenGL, DirectX). [Learn more about Open Visual Cloud](#).





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