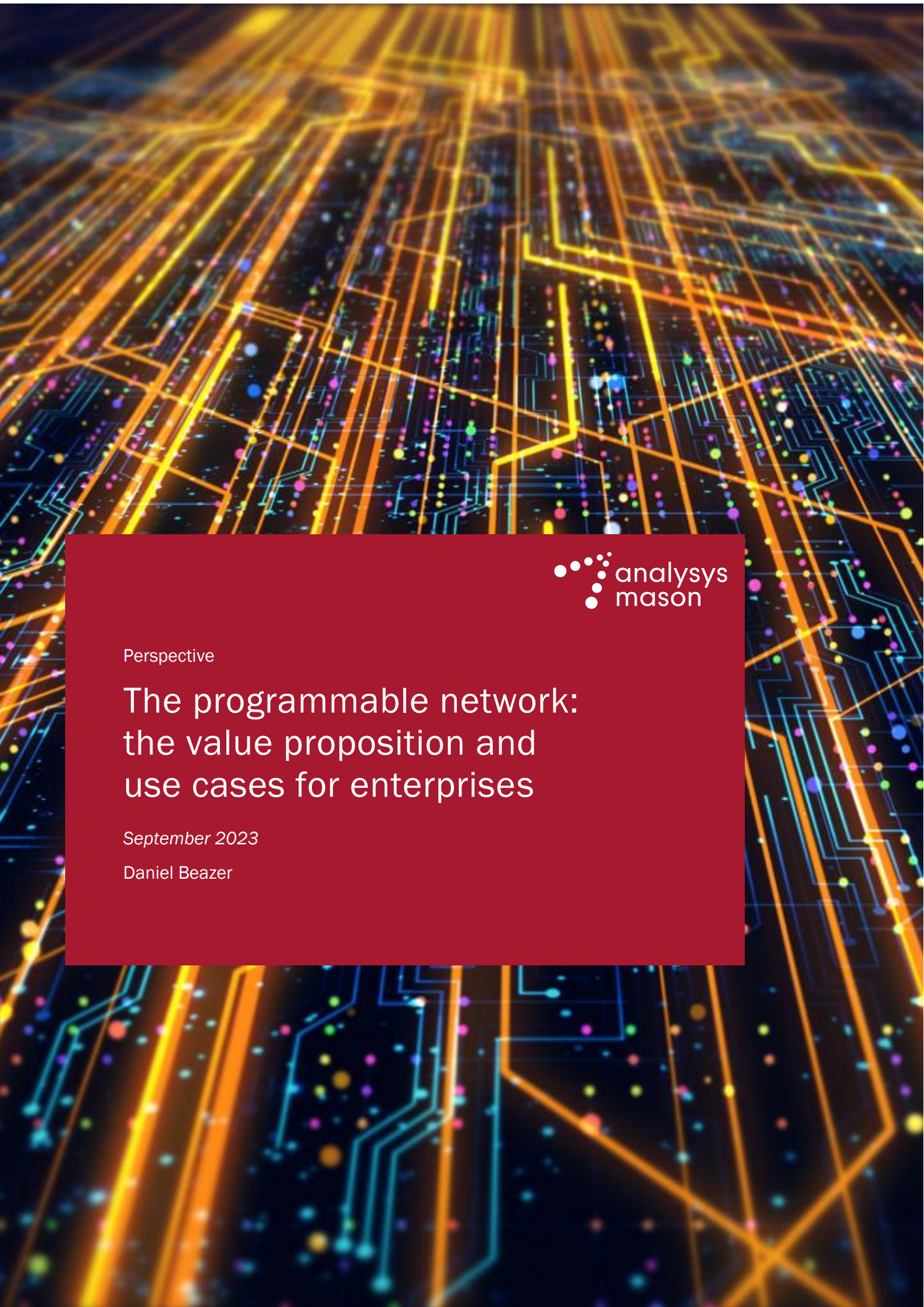

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Perspective

The programmable network: the value proposition and use cases for enterprises

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1. Executive summary

The arrival of cloud computing caused a revolution in enterprise IT because it gave developers control of compute and storage resources that were previously the domain of proprietary operations staff. Today we are seeing a second wave of disruption and innovation, but this time it is the network, which was hitherto controlled and managed by operators, that will be placed in the hands of application developers. As with cloud computing, the ability to embed advanced network capabilities into application architecture will open up a new set of potential use cases, enabling enterprises to generate new revenue and increase productivity.

1.1 Networks are becoming more programmable, which creates new revenue and cost-saving opportunities for enterprises

Operators plan to expose network capabilities that will give developers comprehensive visibility and control over capabilities such as network performance, security and quality of service. The ability to embed such capabilities into application pipelines so that applications can control their own connectivity will drive this next stage of digital transformation, creating a range of opportunities for enterprises.

- **Enable Industry 4.0.** Mission-critical industrial applications that interact with the network in a seamless automated manner will enable enterprises to realise their Industry 4.0 ambitions.

- **Boost innovation and the creation of new services.** The ability to route traffic and control quality of service will enable enterprises to create immersive communication experiences or control things remotely across diverse networks and geographical areas.

- **Solve operational and other internal process challenges.** The deployment of guaranteed connectivity supports applications that improve worker safety and the implementation of granular security controls enables enterprises effectively to manage the post-COVID distributed, remote workforce.

Programmable networks are at an early stage of development but use cases are already emerging in these categories, which take advantage of advanced network capabilities. The three most advanced use cases support AI-assisted video inferencing, accident prevention and remote visibility and control. We examine examples of such use cases in detail in Section 3 of this report.

1.2 Taking advantage of the programmable network opportunity will require a long-term strategy and the right partners

This report discusses how enterprises can successfully take advantage of a programmable network and the developer platform that will give them access to its rich set of features and capabilities. This platform may be used by the enterprise's IT department, or by third parties such as systems integrators or software suppliers. Enterprises will need the following.

- An understanding of which programmable network use cases and features will be most valuable to their business objectives, which will enable internal stakeholders to start building a business case for programmable networks. The emerging use cases for programmable networks are outlined in Section 3 and how enterprises can go about effectively deploying them is discussed in Section 4.

- Access to a platform that exposes network capabilities and aggregates them across multiple networks so that enterprise developers do not have to work differently with the same network features provided by different operators. The platform should make it easy for enterprise developers to access network capabilities and to call them within their application pipelines.

- Engage with a broad ecosystem across the programmable network value chain, including application partners that will give enterprises access to network API-enabled applications, partners that can provide the appropriate security and regulatory frameworks, and partners with use case and vertical expertise that can help to source or support the other parts of the value chain such as devices, connectivity and spectrum.

2. The value proposition of programmable networks for enterprises

The network capabilities that promise these dramatic improvements in processes, and digital transformation across industrial systems, are exposed through application programming interfaces (APIs). The concept of API-based programmable networks is relatively simple. Communications service providers (CSPs) are allowing third parties greater access to network capabilities. This is accomplished through APIs that automatically call up these capabilities when requested by an application.

Up to now, these functions could only be activated and managed by the network owner on behalf of the customer. Opening up the network will allow third-party developers in enterprises and elsewhere to embed network capabilities into their application architecture, generating new revenue and cost-saving opportunities. Figure 1 provides some examples of key programmable network capabilities that enable enterprises to benefit from enhanced features of 5G networks.

Figure 1: Programmable network APIs, their functions and sample business benefits

API	Function	Benefit
Edge	Routing traffic	Routing traffic to nearest server to improve performance
Quality of service	Stable latency	Reliable connectivity to improve process efficiency
Device location	Detects physical position of end user devices	Fraud detection

Source: Analysys Mason

5G will be instrumental in driving the adoption of programmable networks. Enterprises can take advantage of the transformative capabilities of 5G networks in a much more programmable, integrated and customisable manner through programmable networks and APIs to enhance automation, optimise operational efficiency, and achieve new levels of productivity. This is particularly so for industry where the combination of 5G and programmable networks will play an important role in realising Industry 4.0 use cases.

2.1 Programmable networks will play a crucial role in delivering the promise of Industry 4.0

Industry 4.0, the process by which industries transform their operations by applying new technologies such as cloud, data/AI/analytics, IoT, digital twins and 5G networks, is gaining momentum, driven by global trends. Shortages of skilled labour, the need for greater resilience in supply chains and the push for sustainability are encouraging industries to make large investments to transform their industrial processes, supported by heavily Industry 4.0 orientated government initiatives such as Made in China and Made in Germany.

The goal of Industry 4.0 is to create intelligent, interconnected and integrated industrial systems that can increase differentiation, drive innovation and growth, and produce industrial goods at lower cost. The digital transformation process that will bring it about will elevate connectivity to an importance that it did not have in Industry 2.0 and 3.0 settings, bringing benefits and process improvements to industrial applications through the enhanced features of 5G connectivity. This will help Industry 4.0 to achieve the following.

- **Interconnected and integrated systems.** Interacting with the network in a seamless automated manner through APIs will enable operational technology (OT) applications and current IT applications to leverage 5G and Industry 4.0 capabilities; the resulting programmable network will enable enterprises to accomplish production in a flexible, scalable manner enabling for example the control of massive numbers of devices and sensors in real time.

- **Intelligent systems.** Programmatic network capabilities can be combined with artificial intelligence/machine learning in multiple industrial settings to improve assembly line productivity and flexibility; analytics based on sensor data from an assembly line using API-based traffic prioritisation can be used in real time to re-position robots using 5G's hyper-accurate positioning.

- **Lower costs.** APIs essentially enable applications to communicate with the network without manual intervention of any kind, and therefore programmable networks will increase automation and reduce costs; for example, scheduling hundreds or thousands of industrial applications and in real time cannot be carried out manually or even with conventional automation approaches, but will be possible with 5G.

2.2 Programmable networks can boost innovation and help to create new services

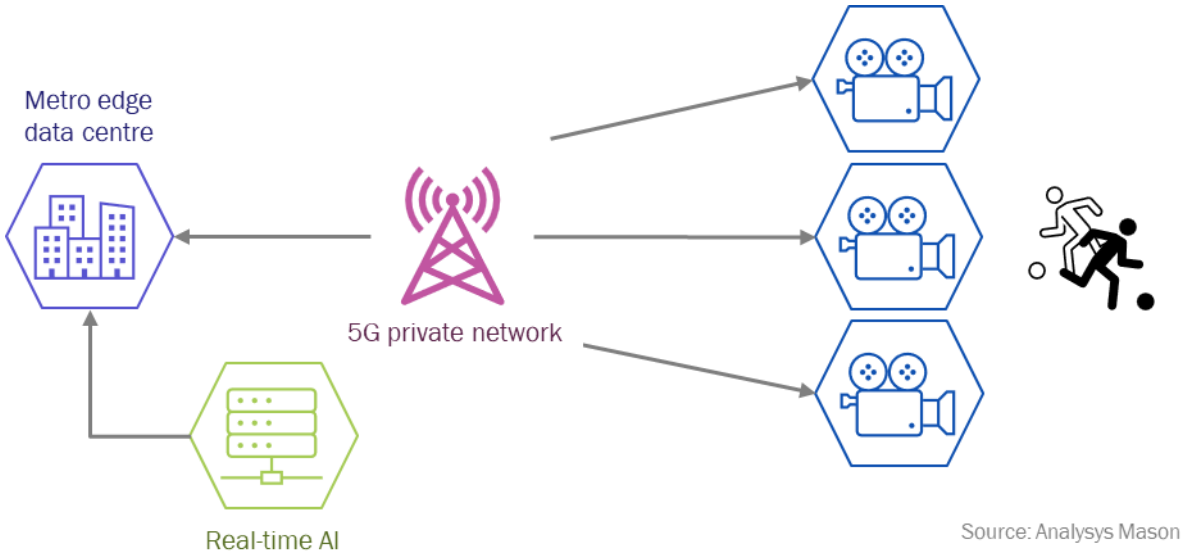
In addition to the increased operational efficiencies and productivity levels, programmable networks will play a pivotal role in driving innovation and facilitating the rapid development and launch of new products and services in enterprises. Some of the key capabilities that programmable networks provide and their potential areas of application include the following.

- **Local/temporary data processing.** Quality-of-service (QoS) APIs combined with cloud-based AI/ML can produce benefits across verticals; for a civic authority, traffic flows can be improved by real-time traffic light management using local AI/ML of data from cameras across a geographical area; real-time data transmission from one set of cameras can be prioritised over others in the area according to traffic volume, or time of day, using the QoS API (Figure 2). In a broadcast setting, the combination can substantially reduce the need for on-site equipment; for example, broadcasters' use of radio trucks and other equipment when covering live events or sports. AI/ML processing does not need to occur on site and can be located in a metro edge cloud node.

- **Immersive communications.** QoS APIs can enable latency-sensitive holographic calls across multiple networks, dramatically improving quality, which will in turn drive adoption of this immersive early metaverse-type application.

- **Real-time experiences.** In the gaming industry, edge APIs can route traffic to the nearest server to an end user and QoS API simultaneously controlling latency and throughput; the combination enables the control of remote objects such as racing cars, opening up new opportunities for new games that are played in real time against players in different countries.

Figure 2: Schematic of QoS API enabling AI-assisted real-time camera coverage of live sports events



2.3 Programmable networks will help enterprises to address their immediate operational challenges

Enterprises need to increase revenue while running operations efficiently and cost-effectively. Enterprises that deploy applications that leverage programmable networks can get an immediate return on their investment and will benefit in the following ways.

- **Improved worker safety**: In hazardous environments, the QoS API can offer guaranteed predictable connectivity that will reassure companies that workers can be warned of unexpected dangers and remove themselves from harm. In addition, 5G's low-latency capabilities enable warning messages to be sent to on-site workers quickly and reliably.

- **Increased factory productivity**. Companies in manufacturing and logistics are deploying more autonomous, mobile systems that will depend on real-time data and will need the granular guaranteed throughput and latency that the QoS API can provide; for example assembly line productivity can be improved through rapid local AI/ML processing leading to increased rates of fault detection.

- **Enhanced events and temporary exhibitions.** Ingress and egress are frequent logistical problems for live events; local (either on site or in a local cloud) AI/ML inferencing can speed processing, with the QoS API ensuring the reliable dynamic transfer of video to the analytics platform.

These use cases are immediate business needs, but only initially. In each case, the enterprise in question will seek to reap the benefits of 5G and APIs by using the platform for an increasing number of applications and use cases. In the live events use case for example, the event owner could go on to use device location APIs to detect false ticketing or other fraudulent behaviours at the event. Thus, these tactical use cases can be properly seen as the first tentative steps in a process of digital transformation.

2.4 Programmable networks can address enterprises' complex technology, connectivity and security challenges

Enterprises face the following technical and operational challenges today as they seek to achieve their business goals.

- **Inflexible operational technologies.** Control and process systems in manufacturing and infrastructure that are monolithic, difficult to scale and proprietary.

- **Restrictive networks.** Cabling in warehouses restrict automated guided vehicle (AGV) movement, technologies like Wi-Fi with limited outdoor coverage, connectivity insufficiently reliable to support real-time vision inferencing.

- **Security and performance.** Enterprises need to support a distributed workforce, enabling access to applications across multiple networks while meeting security and performance goals. Industrial companies are also unwilling to expose core intellectual property or data that is sensitive from a regulatory perspective, such as videos of employees, to public networks or public cloud.

Programmable networks have features that can resolve such issues as well as assisting enterprises with their broader Industry 4.0 objectives. These capabilities are becoming available for enterprises and their developers embedding connectivity into AI/ML and other classes of application, improving productivity and performance. APIs that control traffic flows can improve the efficiency of traffic management systems, and a 5G private network will eliminate cabling, improve coverage and deliver guaranteed connectivity. APIs that can granularly manage security controls will enable enterprises to manage application deployment across multiple countries and networks. The programmable 5G network can also protect sensitive data with zero trust connectivity. Combined with 5G's network slicing capabilities, it will enable enterprises to establish ephemeral sessions with devices in the field that can be terminated after short periods such as the time it takes to complete a software update.

3. How enterprises can start to use programmable networks today

3.1 Emerging categories of use cases

Programmable networks are still at early stages of adoption but already we are seeing use cases using traffic prioritisation, ultra-low latency and other programmatic features (Figure 3). These emerging use cases fall into three categories: video inferencing and AI, remote control and accident prevention.

Figure 3: Early use cases of programmable networks

Enterprise	Enterprise use case	Network API or other network benefit	Nature of API deployment	Business benefit to end user
Cinfo	AI/ML directed cameras for live sports events	QoS	Single request to call	Cost of live broadcasts substantially reduced
DriveUAuto	Remote control of autonomous vehicles	QoS, also ultra-low latency	Dynamic	Reduction in cell usage
Intelligent Traffic Control (ITC)	Real-time management of traffic light systems	QoS	Dynamic throughput adjustment	Reduction in traffic congestion in urban environments
Matsuko	Holographic calls	Edge API (routing to nearest server), quality on demand (QoD)	Single request to call for edge API, dynamic for QoD	Improvements in quality of holographic calls
Sinfosy	Accident prevention on motorways	QoS (predictable), 5G low latency	Single request to call	50% latency improvement in single cell
Vrombr	Remote live car races	QoS (throughput and prioritisation)	Dynamic during game	New revenue stream for gaming and entertainment companies

Source: Analysys Mason

Inferencing and AI

In this use case category, enterprises use programmatic networks to enable or enhance real-time, actionable AI/ML gathered from cameras and sensors. The large storage and processing needs of inferencing and AI make off-load to the cloud expensive. As local processing is both practical and economical, this use case has an attractive ROI for enterprises.

- Cinfo (streaming of live events) sends 50 commands per second out to cameras. Using QoD API enables cameras to seamlessly follow direction play on the sports field. The API used is a single request to call, and the benefit to enterprise is a reduction in the cost of outside broadcast.

- ITC reduces traffic jams in Tel Aviv with dynamic traffic light programming. The solution uses QoS E (latency stable under congestion) and QoS S,M,L dynamically to prioritise video camera traffic (prioritised small, medium, large throughput). The business benefit for Tel Aviv city is the reduction of traffic jams.

Accident prevention

In this use case category, enterprises look to use the low-latency capabilities of 5G combined with QoS to improve the safety of potentially hazardous environments.

- Sinfosy is a solution that improves safety on motorways by communicating from one vehicle to another in milliseconds to prevent pile-ups. Sinfosy argues that Wi-Fi and 4G latency are too high to accomplish this and therefore uses 5G. Sinfosy is also using predictable QoS (single request to call). The business benefit is a 50% improvement with the API in terms of latency from a congested cell.

Remote visibility and control

Enterprises are using network APIs that guarantee network performance and reliability, across several networks, enabling enhanced remote communication and /or control.

- Vrombr: remote reality – taking control of a real object remotely, in this case a racing game for smartphones. People connect from all the world. APIs are deployed dynamically to control latency and to tie throughput to workloads. The benefit is to provide new services and revenue streams for gaming companies.

- Matsuko: holographic calls from smartphone rendered in cloud using QoD, which prioritises traffic deployed by a single request and edge API (a routing API that directs traffic to the nearest rendering server) deployed dynamically. The business benefit is higher-quality holographic calls.

- DriveU.Auto: teleoperation, providing connectivity to autonomous vehicles for remote management by using latency API deployed dynamically. The business benefit is the remote management application runs more cost effectively, only using half the cell, also the availability of ultra-reliable low-latency connectivity.

4. How enterprises can boost their application portfolio by embedding programmatic network capabilities

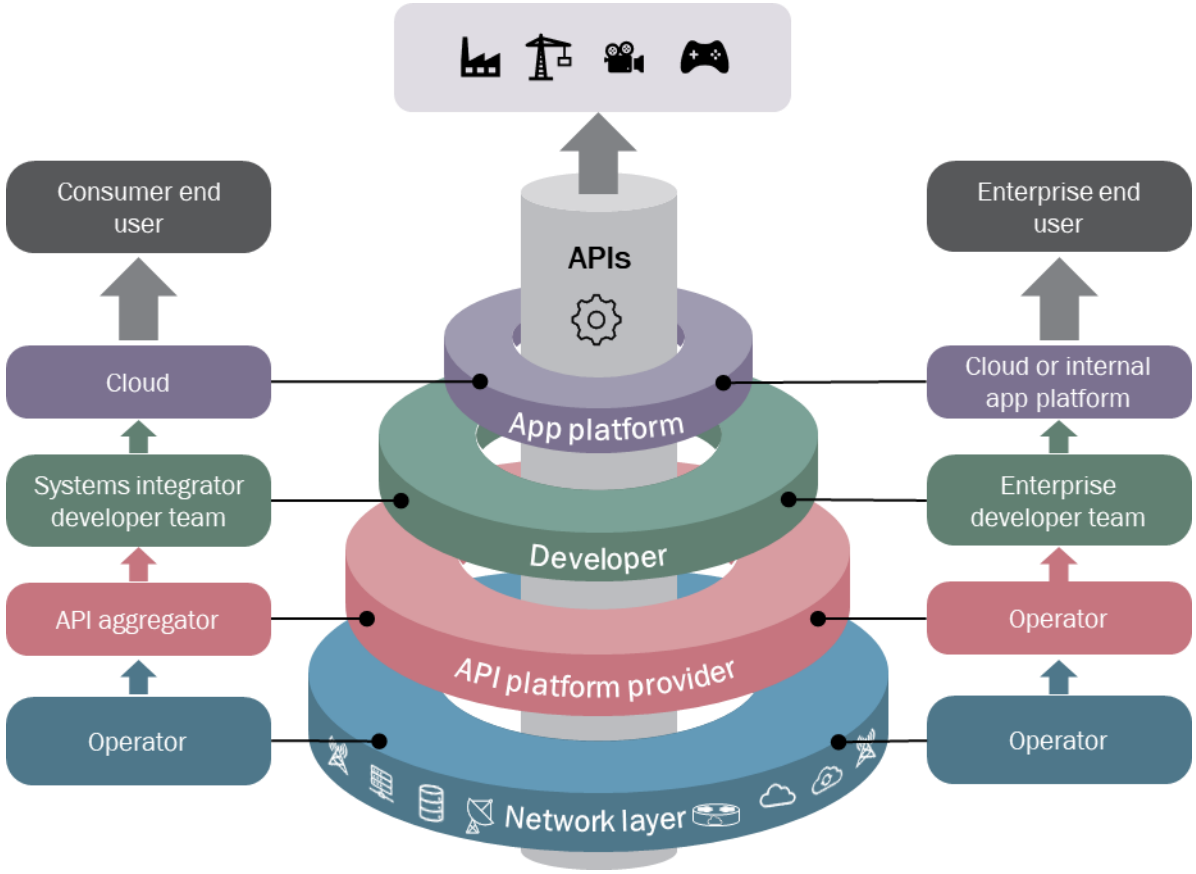
Enterprises that seek to embed network capabilities in their application architecture will be able to obtain programmatic networks from a variety of sources. Enterprises will have to decide whether to go directly to a network operator or indirectly through a third-party platform. They will also have to assess any platform carefully to make sure it possesses the features that are necessary to support a successful programmatic network deployment. Lastly, enterprises will need to be sure that:

- the solution partners possess the necessary supply-chain ecosystems and have the capability to embed appropriate security features into the application and device lifecycle
- the application vendor partners are aligned in their approach to embedding network capabilities.

4.1 Enterprises can gain access to programmatic networks directly, indirectly or via a hybrid model

Enterprises that are looking to use programmatic networks have several modes of deployment and in each the role of the provider of the programmable network platform, the developer team and end user differ. It is therefore important to understand the value chain for programmable networks and who plays what role in each part of the chain (Figure 4). Taking control of network functions that have always been the private domain of the operator inevitably involves many parties and layers and is also at an early stage of evolution. The value chain for the delivery of these new products and services has four layers underneath the end user.

Figure 4: Two API use cases demonstrating the different parts of the value chain



At the top of the stack, is the **end user (consumer or enterprise)** using a new product or service that leverages programmable networks or, alternatively, an enterprise looking to improve internal processes or bring these new products or services to market.

The next layer in the chain is the **developer** who writes applications on the **app platform** that can call up network functions via APIs, improving performance, reliability and security as mentioned above. This developer could be working for an enterprise or for a systems integrator that is building the service for a customer or looking to sell such a service to a customer. The application built by the developer will then be run internally within the organisation, hosted by a systems integrator or externally on the cloud.

At the lower layers of the chain is the network whose capabilities are exposed by API to the layer above it which consists of an API platform that provides an interface to developers and deploys and manages the APIs lower down. It could be provided by the operator itself or by a third-party aggregator. It is also possible to use a hybrid model that is going directly to operators for some APIs functions (typically more mature, commoditised CPaaS-like offerings such as SMS and video), while using an aggregation platform for more application-oriented APIs such as QoS and edge.

Several operators offer QoS edge API and discovery APIs as a service. Although the service is in beta, as we have already seen in Section 3, there are already real use cases. The aggregation space is more of an emerging market and commercially available platforms are expected soon. Three groups are investing in the components of such a platform although they have not necessarily brought them together into a single solution yet. CPaaS vendors such as Vonage and Twilio already have well-established businesses that package lower-level network APIs, such as SMS messaging, and they naturally want to extend their services to more complex programmatic requirements. Several vendors have also announced plans to build an aggregation platform that will aggregate

multiple network APIs and present them as a unified interface for enterprise developers. Several operators are in the early stages of releasing a programmatic network platform, either using their own APIs or more usually using those of a standards group such as CAMARA or those of an aggregator like MobiledgeX. It also likely that new entrants will join the market, for example, public cloud providers that have already made advances into the private network space by bringing 5G offerings to market.

4.2 Considerations for enterprises when looking for a partner that can expose network capabilities

Enterprises need to ensure the platform they choose for exposing network capabilities can properly aggregate across all the networks that the enterprise wishes to reach, provides a platform that developers find easy to consume, and does not lock the enterprise into a closed ecosystem.

Aggregation across multiple networks. Enterprise developers will expect to develop once and have their applications work across any network. They will want access to ultra-low latency and hyper-accurate positioning capabilities and to deterministic routing across network domains to ensure consistent quality of service end-to-end. Operators may, however, prefer to offer their own set of APIs or use those of a third party such as those obtained from a standards body such as CAMARA. CAMARA should not be dismissed as it is signing up members quickly and is using a GitHub code repository model that will hasten development of its currently small API set. Enterprises will have to be confident that the devices and end users that their applications need to support are on the operator's network or reside on an operator network that use the same APIs. Previous attempts by operators at establishing common network APIs do not inspire confidence and the requirement for deployment across networks points to an aggregation platform that can sit in between the developer and CSPs.

Easy-to-consume platform. The aggregation platform mentioned above could also address usability issues, which will hinder the adoption of programmable networks. Enterprise developers have little interest in network engineering. Enterprises will be unwilling to code to a 5G standalone core or across multiple individual networks. To access and incorporate a wide range of network capabilities into the applications, enterprises need the same sort of easily consumable platform that they have become accustomed to using in the public cloud.

Open platform. Enterprises need to be careful to choose a platform that supports open APIs as well as aggregating across multiple networks as mentioned above. Enterprises should be wary of engaging with vendors, service providers or public cloud providers that lock their customers into one API ecosystem. Open APIs will play a critical role in establishing common standards and models of engagement that are needed to facilitate the embedding of network capabilities into Industry 4.0 applications. A platform that supports open APIs will also have the advantage of being able to be extended to support network and application innovation in the future.

4.3 Considerations for enterprises when looking for partners in their broader ecosystem

Software vendors need to embed network capabilities. Enterprises need to select software vendors that embed network capabilities into their application architecture. Taking advantage of the opportunities provided by embedding network capabilities into application architecture requires a change in current attitude of the application architects, who need to be more aware and make use of the benefits that exposed network capabilities can bring. Our earlier report, *NPaaS: operator strategies and the implementation of network APIs*, included a developer survey and noted that there are encouraging signs that the developer community is willing to use programmable network features, but enterprises need to ensure that they procure applications from third parties that have built in access to network capabilities into their applications. Their application vendors should

also be using a platform that gives them broad access to any network operator. Enterprises need consistency and do not want to be in a position where it is not possible to run an application in one branch because it cannot get connectivity to a specific operator's network.

Solution partners should have a use case-centric ecosystem. As demand for programmatic networks will be rooted in individual use cases or vertical-specific use cases, it makes sense for enterprises to consider partners that have tailored APIs into packages and built associated services around specific use cases such as mentioned above in Section 3 (inferencing and AI, risk reduction and remote management). The partner will have also built an ecosystem of software hardware providers and component suppliers around these use cases.

Live event organisers and broadcasters would find a service that bundled the QoD API (AI/ML directed cameras) with the deterministic security and device location API (consumer device location to protect content/prevent fraud) attractive. The APIs could also be integrated into widely used broadcast platforms, either on the consumer side (OTT platforms) or on the production side (remote control platforms for cameras). The partner need not uniquely serve one vertical, as the benefits of exposing network capabilities can be applied across multiple verticals.

Enterprises need partners that can provide the necessary security framework. Enterprises need to find partners that have expertise in areas that are a high priority for enterprises, such as security. The opening up of network functions is a significant increase in attack surface and APIs can be vulnerable to injection attacks, unauthorised access and other misuse. Although enterprises that deploy network APIs are not as exposed as those using them for web applications, they will often use them to process and store critical data and IP. Network APIs will also often be required to operate in unsecure temporary environments, such as live events or remote and hazardous locations, and a security solution that covers the whole stack will be an essential requirement for enterprises.

The 5G network is well-suited to supporting enterprise requirements in this area. It is designed to support enterprise zero-trust networking concepts because it can expose security features through APIs to Industry 4.0 application developers. This allows developers to create secure application pipelines with the appropriate quality of service for a specific use case.

5. Conclusions and recommendations

Programmable networks are in their infancy but emerging use cases are already showing the revenue generation and internal efficiency improvements that they can bring. First movers are already deploying these next-generation networks and gaining a competitive advantage, so it is essential that enterprises take the right steps immediately. We provide the following recommendations.

- **Enterprises need access to network capabilities.** Enterprises need to embed network capabilities into their application architecture for the same reasons they need to adopt cloud-based infrastructure: to be able to innovate, create and improve new products and services, and drive internal efficiencies. Video inferencing, worker safety and remote visibility and control are three emerging groups of use cases but programmable networks will have a much wider application. Embedding device location into an application will be beneficial to many consumer-facing applications and enterprise applications. Being able to programmatically control network quality of service and routing will also bring benefits across application

types and specialisms. Similar improvements can be brought to bear on applications that support internal processes and functions, generating cost savings and efficiency gains.

- **Enterprises need to take advantage of the programmable network opportunity now.** If enterprises fail to take advantage of this opportunity, the risks are significant. As mentioned above, the application of programmable networks is wide and most application and business process can be improved by having network features embedded. Enterprises risk falling behind their competitors if they do not look to see where they can innovate and create new services and products, or enhance existing ones, or improve internal processes.

- **Enterprises need to take steps to ensure that they are at the forefront of this development.** Although this is an immature market, it is attracting investment across the value chain and there will shortly be products and services on the market that will support programmable networks across their lifecycle. When choosing products and partners, the priority for enterprises will be to ensure the applications will be able to run across countries where different networks will be used to access it. This will involve dealing directly with an aggregator platform or with an operator that is using or has created such a platform. Enterprises also need to seek out an ecosystem of application, device, connectivity and security partners that have experience within the enterprise's vertical and use case, and the capabilities to provision manage and support a programmable network deployment.

6. About the author

Daniel Beazer (Senior Analyst) leads Analysys Mason's *Edge and Media Platforms* research programme. His research focuses on the key building block technologies and architecture of the edge computing infrastructure currently emerging to support the delivery of applications and services for 5G, media, entertainment and other industries. Before joining Analysys Mason, he led Structure Research's Edge, 5G and Cloud practice. Daniel has worked extensively in the internet infrastructure industry in management and strategy roles and has several years' experience working as a consultant for leading vendors and investors in the space. He was educated at Oxford University where he read Ancient History and Philosophy.