UKTIN

Future Capability Paper

Artificial Intelligence

Executive Summary

This paper is one in a series of reports on future telecom capabilities in the UK, with the sole focus on Artificial Intelligence (AI). AI serves as a catalyst to drive the transformation of the telecommunications industry, enabling its growth by leveraging advanced algorithms and data analytics. In parallel, telecom networks are one of the critical infrastructures that play a crucial role in facilitating the development and deployment of AI technologies, serving as an enabler for the widespread adoption and utilisation of AI across the sectors.

In the current trends, AI has seen significant consideration in 5G and beyond. Furthermore, the complex interplay between AI and Telco in the coming 6G era leads to opportunities for Telco networks, where new ways of operation, services and business are arising from a dynamic mix of cutting-edge technologies including network, AI, data, and compute towards an AI-native 6G vision.

It is changing the landscape, without leaving out the incumbent players, towards a group of innovative newcomers, system integrators, Small and Medium-sized Enterprises (SMEs), and research entities. Rapid and transformative changes, possibly driven by ascendancy of AI advancements such as Generative AI (Gen AI), are also expected to bring new entrants, and bring in strategic shifts among the stakeholders, reshaping the Telco industry with innovation and adaptation.

Although some of these technology trends are evident, the rapid pace of advancement in the field of AI far outpaces the traditional decade-long planning cycles for each generational upgrade, to which the Telco industry is accustomed. This accelerated rate of technological change poses considerable challenges in analysing the Telco AI landscape and its evolution over the next 5-10 years, even for experts.

This release of the paper is a result of comprehensive analysis conducted in the UKTIN AI Expert Working Group on the role AI plays in telecommunications, through their understanding of the status quo and emerging trends and technologies.

The paper provides coordinated, open, impartial, inclusive, and community-driven views from technical, economical, business, and societal perspectives, particularly on the new opportunities and challenges for the Telco industry. This analysis leads to recommendations on AI technologies supporting telecom R&D policies and interventions by the government. The central ambition is to create a shared public and private sector strategic vision of the Research, Development, and Innovation (R&D&I) opportunities for AI in UK telecommunications for the next 5-10 years. Topics considered in this report take full account of current Telco marketplace priorities for the industry, with particular attention to sustainability, diversification, resilience, and developing a wider supporting ecosystem of AI-driven, data-driven services.

The paper aims to focus on Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis of the key topics: Architecture, Infrastructure, Data, Network Testing with AI, and Services and Business. Cross-topic subjects on Economy, Sustainability, Skill Gap, Ethics and Regulations, and AI Security are then addressed. They are followed by the Summary of Competitive Analysis of UK, and finally the Recommendations from the study so far.

The group acknowledges that the UK exhibits notable strengths in AI, evidenced by a stronger starting position to capture the AI dividend than Europe as a whole, and is in the top quartile of countries on AI readiness (1).

The success of AI systems heavily relies on a profound understanding of the Telco domain, and the UK's expertise in telecommunications and wireless networking provides a crucial foundation. The country's history in semiconductor and processor design, coupled with a robust test and measurement industry, positions it as a leader in creating fundamental building blocks for modern computing. These strengths, spanning from processor design to AI innovation, showcase the UK's prowess and readiness for R&D&I in the realm of AI.

The group identified that AI presents significant opportunities in the telecommunications industry on reducing the costs and expanding new revenue streams. The rapid evolution of AI creates fertile ground for innovation on network operation. This is exemplified by AI-driven network energy saving and anomaly detection to significantly reduce network operational expenditure (OPEX). Emerging AI-driven technologies and services in the network, including network data and service exposure, along with AI-driven customer services, can position companies as Technology Company (Techco) leaders in the evolving Telco AI ecosystem, and expands new revenue streams for Telco.

(1) https://www.mckinsey.com/featured-insights/artificial-intelligence/artificial-intelligence-in-the-united-kingdom-prospects-and-challenges

The concept of 6G being AI-native(2,3) opens doors for massive innovation and substantial investments, with a goal of growing Telco industry and the ecosystem around it. This is supported by the UK government's early AI research(4) into the recent wireless infrastructure strategy(5) in increasing the market deployment of AI and Machine Learning tools to optimise network performance. Another example is DeepMind's pioneering research at Alan Turing Institute in London.

An issue will be retaining AI skills within the sector, this is challenging due to high demand from other industries trying to adopt and use AI, leading to talent competition. Although the UK has invested in supercomputer facilities, it is considered inadequate due to rapid Graphics Processing Units (GPU) chip advancements. Hyperscalers such as Google, AWS, and Azure, are actively engaging with Telco operators towards the cloudification and automation of network architecture and operations. The key gaps in this area are found to be:

- Lack of large and specialised Telco datasets and relatively higher barrier for data sharing in the UK.
- Absence of Radio Access Network Intelligent Controller (RIC) vendors, network equipment vendor development and NetApps Independent Software Vendors in the UK.
- Challenges in growing and retaining AI skills within the telecom sector.
- Potential transformation of the telecom industry relying on hyperscalers outside of UK, resulting in potential reduction in control over national critical infrastructure.
- The concern of supercomputing centres being built in the UK may not be equipped with the most up to date GPU clusters advancement compared to the hyperscalers(6).
- Concerns about centralisation of development and security issues with US-based hyperscalers and semiconductor players.

The group has considered a number of typical Use Cases (in Annex A) where the deployment of AI technology has a significant impact in respect to;
i) Network and infrastructure, with focus on automation due to the complexity of the deployed technologies;
ii) Services and Network Operations, with focus on effectiveness or productivity;
iii) Services delivery with focus on end user's experience.

Based on the comprehensive analysis on opportunities and gaps to catalyse AI in Telco, with a view of generating real R&D and business impacts, the group has reflected on and carefully selected four Recommendations to help boost innovation and catalyse new opportunities.

(2) Task-Oriented 6G Native-AI Network Architecture
(3) 6G - The next hyper connected experience for all
(4) New ten-year plan to make the UK a global AI superpower Government press release
(5) UK Wireless Infrastructure Strategy
(6) The Economist - How to make Britain's AI dreams reality

SUMMARY

Summary of Recommendations

RECOMMENDATION 1: FUTURE NETWORK PLATFORMS:

Create a Future Network Platform and Innovation Program for co-innovation and experimentation of AI transformative capabilities in future Telco with stakeholders.

- Catalyse fast track innovations and disruption on AI capabilities in Telco technology, services, and business transformation.
- Develop PoCs that attract third-party buy-in, fostering collaboration and partnership with diverse stakeholders including new entrants and SMEs.
- As a training platform to share lessons learnt and best practices, upskill and reskill workforce to meet the demands for future AI-powered Telco and cloud providers.
- Promote collaboration with international stakeholders to tap into global expertise and attract investments on future Telco in the UK.

RECOMMENDATION 2: OPEN6G TESTBED:

Establish a cohesive 'Open6G' testbed that facilitates the seamless integration and assessment of multivendor interoperability solutions for native AI network elements and testbeds.

RECOMMENDATION 3: UNIFIED DATA ACCESS:

Create unified Data Accessibility Initiatives towards the goal of safely opening network data and facilitating data sharing for the UK telecom ecosystem.

RECOMMENDATION 4: TELCO-AI INITIATIVES:

Form a mechanism to encourage and incubate radical, creative, fresh thinking research translation and adoption from SME and Universities on Telco AI business growth ideas.

In the next release of this paper, the group will review and report on the roadmap for opportunities in R&D&I in deployment of AI technologies for telecom networks and products, to explore future directions for innovation for AI implemented across platforms, from cloud to devices, and to assess further developments over the next ten years.

INTRODUCTION

Introduction, Background, Scope, Trends & Topics

1/ Introduction

This paper aims to review AI and its role in telecommunications, through the understanding of a group of volunteer experts from academia and industry in the UK. The group has been asked to investigate how the emerging AI trends and techniques will lead to new ways of operating the network and delivering services in telecom.

Continuous discussions have taken full account of telecom marketplace priorities for the industry in the UK, with particular attention to sustainability, diversification and developing a wider supporting ecosystem of specialised services.

This group has considered future directions for telecom networks and services, and explored future directions for research, development, and innovation. The ambition is to report on how AI and network interacts across platforms, from cloud to devices, as the connectivity and intelligence converges in the upcoming 6G networks in the future.

In this report we have highlighted five key topics of telecoms technologies where AI has the most impact, and a potential source of radical innovation within telecom solutions, along with example use cases. The key topics reported on in this release of the paper are:

- Architecture & Deployment
- Infrastructure
- Data
- Network Testing with AI
- Services & Businesses

For each of these key topics, we assessed how AI is used, along with its emerging trends and discoveries. This is illustrated with a set of AI use case examples for these key technology topics.

INTRODUCTION

While investigating these key topics, we noted a set of AI-related themes emerged in cutting across all of them. These cross related topics and opportunities are also discussed in this paper:

- Economy
- Sustainability
- Skills Gaps
- Ethics and regulation
- Security

Finally, as this paper relates to the UK telecoms industry, we reviewed the use of AI in telecoms in multiple countries for comparison. This helped provide a summary of the Strength, Weakness, Opportunity, and Threat (SWOT) analysis.

We addressed the five questions posed to the group in its terms of reference and came up with four recommendations in this report.

The structure of the paper is depicted in Figure 1.

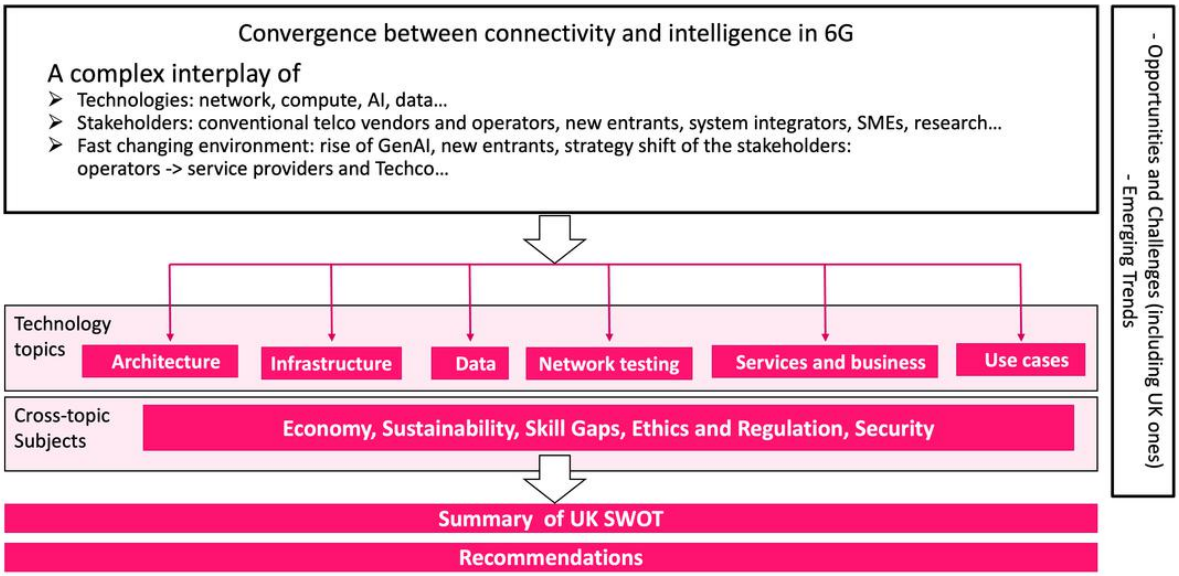

Figure 1 - Structure of this AI EWG paper

1.1/ Background

This section provides background on the role of AI in telecom networks and their future trends.

CONVERGENCE BETWEEN CONNECTIVITY AND INTELLIGENCE IN THE 6G ERA

It is important to understand that the technology refresh within the telecommunication industry starts with the international standardisation stage, driven by the ITU defining a series of desired solutions for the upcoming decades.

The ITU has approved and published the global 6G vision framework and has begun the technical standardisation stages that follow this(7). The delivery of 6G technology will then be specified by ETSI and 3GPP, working together and taking their lead from the ITU definition for technology readiness by 2030. Also UK's international technology strategy(8) considers six strategic priorities which identifies AI among the priority technologies alongside Data.

The ITU 6G framework goes beyond connectivity and aspires to make this new digital experience accessible to every individual, at every corner of our future, including how we are educated, how we work, how we live our day to day lives, and how we interact with other people and machines.

As of now, 6G remains in its early stages. The technological landscape is filled with many potential opportunities. One of the trends we observe is a surge in transformative use cases that emerge as a result of the convergence among connectivity, sensing, and intelligence. For example, AI-enabled Telco services are enabling smart cities and connecting IoT devices. Technology trends, such as digital twins and smart infrastructures, are revolutionising industries such as healthcare with remote diagnosis, optimising logistics with autonomous delivery vehicles, and enhancing entertainment experiences with seamless augmented and virtual reality. The convergence of connectivity and intelligence is driving innovation in the wider society across sectors, including Telco.

(7) IMT towards 2030 and beyond
(8) The UK's International Technology strategy: Chapter 2: Our 6 strategic priorities

Background

AI IS THE FOUNDATION OF REALISING NETWORK, SERVICE, AND BUSINESS TRANSFORMATION FOR TELCO CSPS, DRIVING COST-SAVINGS AND NEW REVENUE STREAMS.

Communications Service Providers (CSPs) are looking to support the growing demand for a variety of services from their consumer (B2C) and business (B2B) customers. This has resulted in greater complexity in network architecture, operations, and deployment, with elevated OPEX as well as Capital Expenditure (CAPEX). On the other hand, the global revenue from CSPs has been declining(9), from $1.9 trillion in 2012 to less than $1.8 trillion last year. Despite some $1 trillion in collective investments over the past five years, the achieved Return-on-Investment (RoI) has been less than 1%. To address this trend, Telco industry has been implementing strategies to leverage AI for cost reduction and expansion of new revenue streams in evolving telecom services and products.

There is increasing evidence showing that AI can enhance network operations, reducing operational costs and enabling efficient resource allocation. AI for traffic prediction and energy saving are great examples where AI has been deployed as part of the network operation for efficiency enhancement and cost reduction(10). According to Vodafone CTO(11), as much as €500m can be saved over three years as a result of applying network automation and digital transformation.

In addition to cost saving, CSPs are looking to expand their revenue stream by providing AI-driven value-added services from their networks. AI holds the promise as a transformative catalyst for Telco CSPs to expand new revenue streams(12) with data-driven, and AI-driven monetisation strategies, for example through the exposure and monetisation of data and network monitoring as a service, that opens up new revenue streams using customer and network data insights.

This Expert Working Group (EWG) noted that whilst the telecommunications infrastructure has innovated substantially over the years, it is delivering services that are expected to get better year on year; an expectation held by consumers, enterprises, and society at large. This EWG also noted that, other than the commercial advantages mentioned earlier as a result of the continued innovation, significant innovations in telecommunications infrastructure have become the driving force behind a better-connected future across all sectors including future healthcare and education. Consequently, it is essential that innovation in telecom networks is steered not only by commercial gains but also by broader societal benefits.

(9) Telco longboat sails for Copenhagen in 'code red' crisis - LightReading Article by Iain Morris
(10) Vodafone UK shares its recipe for energy efficiency - TelecomTV Article by Yanitsa Boyadzhieva
(11) Vodafone CTO: Network automation has saved us €500m in three years - TelecomTV article by Ray Le Maistre
(12) Telco2025: Telcos Need New Revenue Streams, Even As Connectivity Demand Rises (oliverwyman.com)

Background

THE RAPID PACE OF ADVANCEMENT IN THE FIELD OF AI FAR OUTPACES TELECOM INDUSTRY'S DECADE-LONG PLANNING CYCLES TO WHICH THE TELECOMMUNICATIONS INDUSTRY IS ACCUSTOMED.

Many areas of telecommunication systems are governed by and implemented to various normative specifications, created by international standards bodies, e.g., 3GPP, ETSI, IETF (3gpp.org, ETSI.org, and ietf.org) and alliances (ONF, ORAN). These specifications are seeded years in advance by organisations such as the ITU and NGMN, who set the high-level requirements(13) and use cases(14) that signpost the technological direction for the coming generation of specifications. As a result, advancements in each generation of telecom networks have typically been built upon existing technologies and frameworks, allowing backwards compatibility, gradually enhancing capabilities and performance with steady evolution of the system over time, and have historically seen incremental and evolutionary developments, rather than revolutionary leaps.

By comparison, although AI has been in use in Telco systems for approximately the last decade, the initial applications have been focused predominantly on improving call centres' efficiency with chatbots and preventing customer churn amongst other business operations. Only in recent years has the use of AI become widespread in Telco network management, leading to several significant transformations in network operation and services. The rise of Generative AI has created widespread enthusiasm within the industry, with many Telco companies shifting their strategy to embrace Generative AI for customer services and network operation. This accelerated rate of technological change brings impact to the network infrastructure, stakeholders, business models, and innovation, therefore poses considerable challenges to analysing the Telco AI landscape and its evolution over the next five to ten years, even for experts, hence the challenges in producing such a paper.

(13) Framework and overall objectives of the future development of IMT for 2030 and beyond
(14) 6G Use Cases and Analysis - NGMN Publication

Background

THE PAPER

Through extensive discussions conducted in the group with EWG members from industry, academia, analysts, regulators, and SMEs, this first release of the paper presents current findings, including current and emerging trends of Telco AI research, development and innovation, SWOT analysis of selected key topics, and forward-looking opportunities and challenges on potential technological, business, and societal transformations that AI could bring to the Telco industry in the UK. The paper shares the findings of studies conducted by the AI EWG from their individual perspectives and experiences, and based on collective expertise, knowledge, and insights in the EWG.

There are many quotes and variations for defining AI in the literature. For the purpose of this paper, "AI" encompasses a wide range of technologies and methodologies that enable systems to i) conduct learning, ii) reasoning, iii) problem-solving, and iv) decision-making through gathered intelligence through a model used in executing an automation process. Here, we note the OECD definition of AI(15) as:

“a machine-based system that is capable of influencing the environment by producing an output (predictions, recommendations, or decisions) for a given set of objectives. It uses machine and/or human-based data and inputs to (i) perceive real and/or virtual environments; (ii) abstract these perceptions into models through analysis in an automated manner (e.g., with machine learning), or manually; and (iii) use model inference to formulate options for outcomes."

In view of this EWG, "Telco AI" refers to the application of AI within telecommunications industry, encompassing its role in network and business operations, applications, and services, as well as the network capabilities enabling the versatile development, deployment, and exploitation of AI in such systems.

(15) OECD Definition of AI

1.2/ Scope of AI in Telco

AI plays a significant role in the current network and is expected to be even more integral in the future networks. As networks continue to evolve in complexity and scale, AI has already found its widespread applications in the networks. A number of such use cases have been identified and can be found in, for example, the O-RAN Alliance(16), ETSI-ENI(17), ETSI-ZSM(18), ETSI-MANO(19), TMF(20), Open-Slice(21), CAPIF(22) and etc.

The Telco industry has undergone a significant transformation in recent years with deployment of AI as part of their architectures and solutions. Over the past few years, the Telco network has been evolving from plugging in individual AI models in a particular domain and component of the network, to becoming a platform supporting widespread use of AI end-to-end, addressing use cases from operational level to the application and service level.

New use cases are emerging, both due to the fast advancement of AI technologies, and the desperate needs from Telco network operators to ensure long-term business sustainability and competitiveness. There are already numerous AI use cases in the telecommunication industry. For this paper, we provide an overview of the scope of Telecommunication AI use cases and provide a small sample of use cases from three different dimensions:

- Network and infrastructure optimisation that is needed to realise services and operational efficiency.
- Service and network deployments which encompasses systems to manage the lifecycle and operational process for managing services, applications, network, and infrastructure.
- Services and application offered to customer and enterprises.

(16) "O-RAN Use Cases and Deployment Scenarios"
(17) Network Management and Orchestration Using Artificial Intelligence: Overview of ETSI ENI
(18) Zero-touch network and Service Management (ZSM); Requirements based on documented scenarios
(19) Open Source MANO (OSM)
(20) GB1002 Artificial Intelligence User Stories and Use Cases R19.0.1
(21) ETSI Software Development Group for OpenSlice
(22) ETSI Software Development Group OpenCAPIF

Examples of AI applications to Telcos has been illustrated in Figure 2 where each of these three dimensions have quite distinct business drivers which influences the pace of change in each dimension. Table below shows an example for business drivers.

	Network and Infrastructure	Services and Network Operation	Services and Applications
Business Drivers	Manage substantial CAPEX expenditures for Return on Investment	OPEX reduction, new revenue opportunities, Operational efficiency and effectiveness	Customer Revenue focus Customer Quality of Experience

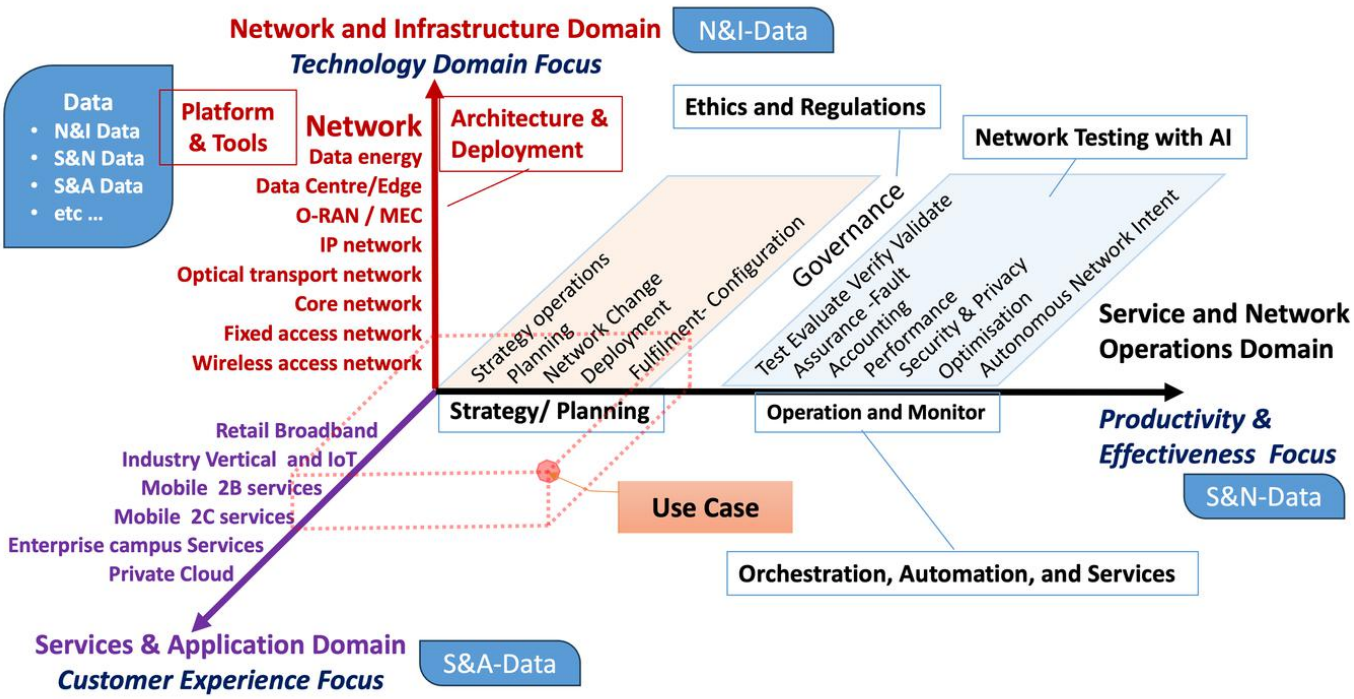

Figure 2 AI Applications to Telecommunications

Scope of AI in Telco

Details of the samples for AI use cases are given in the Annex A. Below we give a brief summary of these use cases.

Management of data is a set of infrastructure platform capabilities to support services, networks, and operations. Exemplar Telecommunication AI use cases related to data include:

- Data as a Service
- Synthetic Data Generation

AI Architecture and Deployment are infrastructure platform capabilities that can support numerous networks, services, and operation scenarios. Exemplar Telecommunication AI Architecture and Deployment use cases include:

- RAN Energy Saving
- 5G Core Performance optimisation
- Quality of Experience (QoE) optimisation

Operation of resilient and secure networks requires testing, monitoring and assurance capabilities covering the full network lifecycle. Network testing is complex and effort intensive. AI presents significant opportunities for Network Testing to:

- Reduce effort in development testing.
- Create more discerning tests that focus on those aspects that frequently lead to operational and interoperability problems.
- Reduce resource demands when testing new capabilities in networks.

More exemplar Telco AI use cases can be found in Annex A for interested readers.

In addition, the group has identified that opportunities of AI applications and resulting new entrants to the market exist in new use cases prompted by emerging network deployment in 5G and beyond, such as Private Network and Non-Terrestrial Network (NTN). These are also addressed in Annex C and D, respectively.

1.3/ Current and EmergingTrends

In this section we highlight a number of current and emerging trends to evaluate the adoption and maturity of AI in Telco, along with a discussion of the future demand for AI Assurance to offer resilience in Telco.

AI ADOPTION IN TELCO:

The path to adopting AI in the telecom industry has seen a shift from cautious exploration to full embracement. Initially, many Telco operators were hesitant to embrace AI due to concerns about the massive investments required and apprehensions about the reliability, safety, and security of AI systems.

However, as the benefits of AI have become increasingly evident, Telco companies have made significant advancement in AI adoption to seize the opportunity. A massive number of pilot projects were initiated to evaluate the feasibility and ROI of AI solutions. UK Telcos have been deploying AI and finding ROI in areas such as network automation, predictive maintenance, customer retention and the services.

Operators like BT and Vodafone also have publicly committed strategies around AI(23,24,25). Telcos have deployed AI within the past 2-4 years, in various domains and for various use cases in Annex A - AI use cases of this paper. Today, in particular as the hype cycle surrounding Generative AI is at its peak, there is widespread enthusiasm within the industry, with a firm belief that AI is key to Telco strategy, from technology to business transformation.

We have noted that Innovative global Telcos are pioneering use of Generative AI in areas such as customer service, but its relevance specifically to the telecommunication industry will emerge when telecom LLMs or telecom foundation models get created. Telecom providers have benefited from use of Conversational AI for customer service, which sets the stage for evolution towards Generative AI in this area for aspects such as call summarisation, multilingual customer service support.

(23) Vodafone CTO: Network automation has saved us €500m in three years | TelecomTV
(24) Artificial Intelligence x Real Economy BT Press Office
(25) Unlocking AI value through a values-led approach - BT Press Office

AI MATURITY IN TELCO:

The Telco industry adoption of AI is now growing significantly with AI spend expected to be about 28% CAGR from 2023 to 2030(26). Some fundamental challenges on AI deployment, such as availability and cleanliness of data, and scalability, transparency and explainability of the ML models, still remain and currently hinder widespread AI deployments in the network. AI integration to legacy networks is another compelling challenge to achieve full autonomous networks, end to end.

Full intelligence across the network requires different platforms, tools, and components of the network to seamlessly work together, encompassing the entire value chain from the operational level to the application level. To maximise the benefits of AI, Telcos must break down silos and create the network and services where AI-driven insights, and actions can flow efficiently within and among the network, as well as to the third parties, for example, through open APIs(27,28).

We believe such transformation in Telco is expected to continue shaping the roles of various players in the ecosystem, creating new business opportunities for Telco operators, vendors, system integrators, SMEs, and new entrants.

(26) AI set to boost telecom market to $11.29bn by 2030 - IT Brief Article
(27) GSMA | GSMA Open Gateway Frequently Asked Questions - Future Networks
(28) Open APIs - TM Forum

AI RESILIENCE & ASSURANCE IN TELCO:

The group identifies that AI reliability, safety and security is critical to the success of AI adoption in Telco. Activities in the UK to push forward Telco AI regulation, ethics, and security, are needed to facilitate full adoption of AI in Telco.

We believe that robust ethics frameworks and governance models need to be established to guide AI development and deployment, addressing issues like bias, privacy, and transparency. AI security measures need to be prioritised to minimise attacks.

We have noted that opportunities such as AI-powered cybersecurity solutions can be employed to detect and mitigate threats and vulnerabilities. Compliance with industry regulations must ensure that AI implementations adhere to legal and regulatory requirements. AI assurance tools and constant monitoring can be applied to maintain reliability; hence this will lead to the AI Resilience of the Telco driven by AI technologies and their use cases.

Although the EU and UK have been at the forefront of developing AI safety and regulations(29); these activities are focused on making frontier AI safe. It is however noted by this EWG that sector-specific regulations, such as regulations of AI in Telco, need to be addressed, and there is a lack of such activities to push forward Telco AI regulation, ethics, and security at the moment. The group has carried out the initial analysis on state-of-the-art Telco ethics and security in this first release of the paper. Further analysis and discussions are planned for the second release of the paper.

In the following section, analysis on AI adoption and maturity that is conducted on selected technical topics will be described, followed by SWOT analysis on specific technical topics, as well as general issues around AI assurance.

(29) AI Safety Summit 2023

1.4/ Study Topics

While addressing the medium-long term role of AI in the Telco industry, the group identified and selected 5 key areas of telecoms technology where AI is transformative, and a potential source of radical innovation. For each of these topics, we assessed the current and emerging trends on how AI is used, and where the potential research, development, and innovation is going. The key topics are:

- Architecture
- Infrastructure
- Data
- Network Testing
- Services and Business

Considering the complexity of a telecommunication network, some of these topics are closely linked, with a degree of overlapping with each other. Nevertheless, each of these topics contributes essential insights to the paper, collectively providing a comprehensive view of the complex interplay between AI and the telecommunications sector.

While investigating Key Topics, a set of AI-related themes emerged cutting across all of these topics. They are discussed in the second main part of the paper:

- Ethics and regulation
- Sustainability
- Skills
- Supply chain
- Economy
- Security
- Standards

Some of these topics will be further developed and studied in the phase 2 of the paper.

All the study topics collectively provides comprehensive exploration of the R&D&I landscape of AI in the telecommunications industry, from the technical, business, economical and societal perspective.

2.1/ Key Architecture

2.1.1/ State of the Art

This section delves into the telecoms architecture and defines how the networks are constructed: the component parts and the interfaces that connect them. It serves as a blueprint that guides network development and operations, enabling the network to meet its objectives effectively and adapt to changing technological and operational requirements. The architecture provides clarity and understanding of the system with a clear, structured framework for the individual network functions.

Complex systems are separated into manageable components, making it easier for engineers, operators, and other stakeholders to comprehend how the network operates. It helps engineers and designers make informed decisions about how to construct and scale the network, as demands and requirements shift, while maintaining overall network integrity and performance.

A handful of Network Equipment Vendors dominate the telecoms network market(30). The complexity of the telecoms systems and the focused effort of system integration led to superior performance and lower costs in network systems from single Network Equipment Vendor. In turn, this leads to MNOs deploying these complete network systems from a single Network Equipment Vendor and with high confidence, albeit locking their network to a single Network Equipment Vendor per region.

There are many Standards Development Organisations (SDOs) involved in defining various subsystems that make up today's telecom networks ecosystem, enabling solutions for connectivity and delivering seamless services across the globe. Below we give ITU, ETSI, and 3GPP as examples, which are by no means exhaustive, but serves as a pointer for relevant discussions in these SDOs:

(30) Worldwide Telecom Equipment up 3 Percent in 2022 - Article by Stefan Pongratz

- ITU: Setting the International goals for global coordination, through "International Mobile Telecommunications" from IMT-2000, IMT- Advanced, IMT 2020 and now to IMT 2030
- ETSI: Defining the European Standards, through a number of Standards Groups,
  - Industry specification group (ISG) securing AI (SAI) (31) (32)
  - Industry specification group Experiential Networked Intelligence (ENI)(33)
  - Industry specification group Zero touch network & Service Management (ZSM) (34)
  - Industry specification group Network Functions Virtualisation (NFV)
- 3GPP: Specification body, organised in different discipline, and working groups
  - So far have delivered 3G, 4G and 5G specifications to ETSI
  - Currently working towards 6G considering IMT-2030 recommendations
  - By 2035 we will see reference to Advanced 6G
- 3GPP: Systems Architecture, SA-WG1, WG2, WG5
  - AI/ML operation splitting
  - AI/ML model/data distribution & sharing
  - Distributed and Federated training
  - Management services for managing AI/ML capabilities / Intent
- 3GPP: Radio Access Network, RAN-WG1, WG3
  - CSI feedback / Beamforming / Positioning
  - Energy Saving / Load balancing / Mobility optimisation

It is worth noting that there are numerous other leading organisations specifying relevant telecommunication technologies as part of the ecosystem, among which are: NGMN, IETF, O-RAN Alliance, GSMA, TMF, TIP, etc that are actively defining a variety of specifications deployed in the telecom networks across the globe.

3GPP has been the primary organisation, with the support of major global SDOs, providing detailed specification for mobile network architecture. In recent years, there has been a significant increase in the discussion of AI-related topics across all working groups in 3GPP where, through the plenary of system architecture, various technical groups take on the challenge of defining the use of AI as a solution within their working documents and specifications.

(31) ETSI AI Report
(32) ETSI Securing Artificial Intelligence (SAI)
(33) ETSI Experimental Networked Intelligence (ENI)
(34) ETSI Zero touch network & Service Management (ZSM)

We understand that network equipment providers (NEPs) work to adopt modern practices and architectures, such as virtualisation and AI, there is an expectation that new entrants into the market could increase the rate of adoption. Over the previous decade, network equipment vendors have migrated from integrated hardware and software functions towards virtualised network functions that can be run-on general-purpose servers. However, this migration is limited to the core network with efforts in the radio access network has been limited so far.

One reason for this is virtualisation is increasingly difficult nearer the radio interface, due to tighter latency requirements, and very large compute workloads. The workload requirements also have different characteristics that make them unsuitable and inefficient to execute on general purpose servers. Network equipment vendors have employed AI to significant effect in certain use cases, such as performance optimisation, energy saving and to improve network analytics and maintenance. However, it is generally limited in its application to specific tasks or goals. Interoperation between the individual AI agents is limited. There is no drive for interoperation of AI from different network equipment vendors at the moment, which limits the possibility of holistic optimisations across networks.

In support of the vendor diversification and to enable new entrants and hence increase innovation, MNOs are working to create new architectures. The O-RAN Alliance(35) was founded in 2018 by 5 prominent MNOs with the aim of defining an open radio access network (RAN) architecture that could be used for the deployment in mobile networks. The objectives were to facilitate disaggregation, virtualisation, and automation and an infrastructure for AI within the RAN part of the cellular network. The Open RAN ecosystem is in its infancy, with small areas being trialled by several MNOs with live customers. The infrastructure for intelligence is centred around a new component, the RAN Intelligent Controller (RIC). The RIC provides a framework for AI agents, with interfaces gathering data from the RAN and enabling control of base stations and setting policy of the network. It is a platform for AI applications, known as xApps or rApps, to execute, with potential for mediation between the xApps and rApps. Their aim is that the xApps and rApps are portable between different RIC vendors, though this has not been demonstrated yet. This architecture allows flexibility in how the RIC might be deployed, for instance either a few in centralised offices each controlling a region, or many distributed across the network linked to cell sites.

(35) O-RAN Alliance

The distributed architectures would utilise an edge compute and could take advantage of federated AI models.

These open standards have gained some traction, with new entrants in the market around the globe. Many of these are focused on the RIC, xApps and rApps. There are also open-source software initiatives that implement the O-RAN architecture(36), such as srsRAN(37) and OAI(38).

(36) O-RAN Specifications
(37) srsRAN Project - Open Source RAN
(38) Open Air Interface

2.1.2/ Emerging Trends

2.1.2.1 AI Native Network

The current approach to integrating Artificial Intelligence (AI) into network management often resembles a patchwork solution, constraining the potential for AI operations in the network to achieve scalability and sophistication.

Complexity in networks increases year on year, along with increasing dynamic performance constraints, which demand ever faster adjustments to keep good performance. These are ultimately best satisfied by automation, removing human operators from the adjustment loops. While automation can be implemented with designed algorithms, machine learning and artificial intelligence models are ideally suited to driving this automation.

Currently, AI applications in networks follow a piecemeal approach, where specific use cases are identified for which a business case can be made, AI solutions are then independently developed in isolation, and subsequently integrated into the network. While this 'plug-and-play' approach of multiple models has been effective for addressing isolated network issues and for specific use cases, it becomes clear that as AI applications become more prevalent across the network, new challenges arise. Multiple AI models, trained on diverse datasets and originating from different vendors, may conflict with each other, resulting in issues like user assignment discrepancies and conflicting objectives (for example, optimising throughput versus minimising energy consumption).

To address these challenges AI native telecoms embeds AI as an intrinsic element of the functionality in all parts of the network life cycle: design, integration, deployment, operation, and maintenance. We envisage that the current approach with AI embedded within the network is going to continue to exist, while at the same time, opportunities are arising in the network to accommodate an AI layer or network intelligent controller that centrally manages and orchestrates AI models while considering their interactions, collaborations, and life cycles. Such a comprehensive solution has the potential to reshape network operation and design, ushering in a new era of efficiency and adaptability.

The ambition of AI native is huge and a pathway to reach it is mapped in a series of levels across the different functional domains that would potentially impact network R&D directions in the next coming years.

2.1.2.1 AI Native Network

ITU report on future technology trends of terrestrial International Mobile Telecommunications systems towards 2030 (IMT 2030) and beyond states 6G as being AI-native, which has accelerated the attention and R&D investment in the concept, as 2030 is the target for large scale 6G deployments for many in the industry. 3GPP are planning for research studies to start in 2024, which initiates the process to publishing standards in 2028. While these are being created, companies will work in parallel to create the functions and products that will deliver 6G in 2030. Even before this, AI native technologies that reach maturity could be deployed in 5G-advanced solutions. 3GPP have indicated that they would like to see early usage of 6G technologies, not least as it helps to drive maturity of 6G. This means the possibilities for AI native are not for the far future, they can be applied as soon as they become available.

The "AI-native" network evolution gives directions of future telecoms technology trends by entities such as ITU and discussed by key players in network equipment manufacturing and cellular technologies, e.g. Ericsson(39), Nokia(40), Qualcomm(41). Whilst work on requirements and specifications for 6G has yet to start, there has been significant activity for a while in the 3GPP standardisation body with working groups RAN1 focusing on AI/ML in the Air Interface for 5G Advanced and the SA developing specifications for "the Network for AI". The O-RAN Alliance has also been developing specifications for RAN management and control, i.e., the RAN Intelligent Controller (RIC). Between these activities, the specifications to provide AI in RAN for 5G and 5G Advanced are in progress.

(39) Ericsson: Defining AI native: A key enabler for advanced intelligent telecom networks
(40) Nokia Bell Labs
(41) Towards an AI-native communications system design

A roadmap developed by Ericsson, that outlines the increased capabilities towards a fully AI native telecoms systems is given in Figure 3.

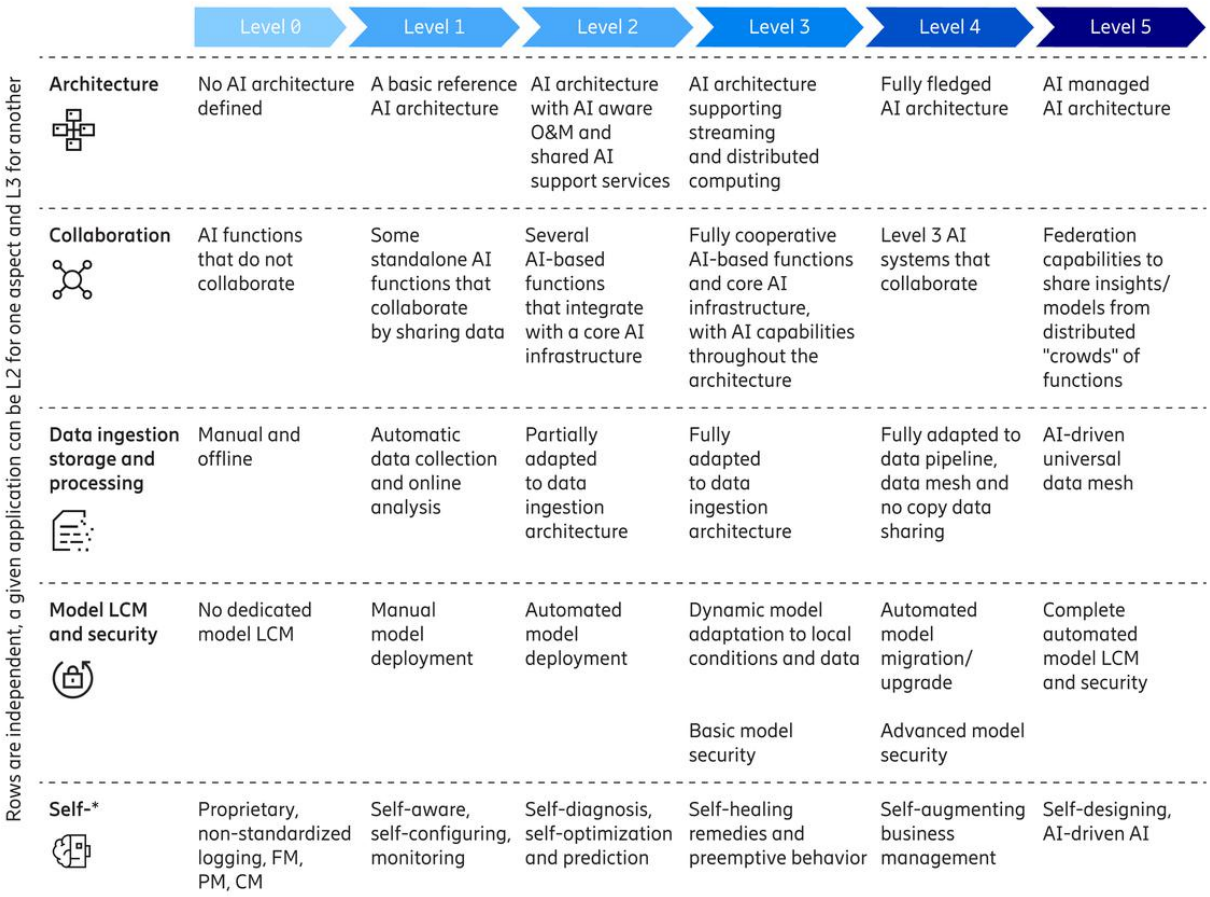

Figure 3 Ericsson model of AI native capability levels(42)

AI-native telecoms integrate AI as an inherent component across all phases of the network life cycle, encompassing design, deployment, operation, and maintenance. This innovative approach opens doors to technological advancements, ecosystem formation, and the inclusion of new entrants in the ecosystem.

(42) Ericsson: Defining AI native: A key enabler for advanced intelligent telecom networks - White Paper

AI-native telecoms represent a transformative paradigm where AI is seamlessly woven into every facet of the network's lifecycle, spanning design, deployment, operation, and maintenance. This holistic approach not only paves the way for technological advancements but also fosters the development of a dynamic ecosystem and the incorporation of fresh stakeholders into the telecom landscape.

The collaborative nature, and the demands for massive data, are likely to shift the architecture to be distributed across diverse network nodes, the cloud, edge nodes, and even mobile devices themselves. This shift introduces new challenges in data distribution, AI compute on constrained devices, and federated learning and inference algorithms. AI will be applied in new domains across the network from digital signal processing to intent-based networking and service provision. There are many specialised and discrete functions which could be replaced by more adaptive and cooperative AI based operations.

The tight integration of AI and network is set to penetrate new domains throughout the network infrastructure, reshaping the design, operation, maintenance, deployment, and service delivery aspects of the network ecosystem. This transformation will redefine not only how these processes are conducted but also by whom they are orchestrated.

While much attention has been given to the transformative role of AI in the context of Telco networks, it is equally important to recognise that the development of the network as a platform is a significant catalyst for the advancement and widespread adoption of AI.

The network, going beyond its traditional role of providing connectivity, is becoming a platform that hosts data, intelligence, communication, and computational resources. This leads to a network that is expected to support data and AI models to compute, exchange, and facilitate the collaboration of intelligent agents everywhere in the network. Such transformation brings new challenges to support AI operation, validation, and deployment, as well as new opportunities for innovative services and business models, impacting the future Telco AI ecosystem.

2.1.2.2/ Disaggregation

The MNOs are pushing for an ecosystem of disaggregation of network component supply chain especially in the mobile network RAN, to reduce the total cost of ownership (TCO) and increase innovation by promoting competition between vendors.

We have seen and understand that there are trends that back re-aggregation, but MNOs believe the market is not well served by the small number of dominant network equipment providers (NEPs), so it is necessary to stimulate new equipment vendors. The size of investment required to build complete RAN or core systems is simply out of reach; for most, if not all, newcomers in the telecom supply chain. Therefore, these telecom systems must be disaggregated into smaller components which can be developed with tractable investments. Further, these components can be targeted by specialists, bringing targeted differentiated innovations to market without the encumbrance of developing a full telecoms network. Access to open interfaces between telecom network entities has been long desire of the network operators communities, such that in recent years created O-RAN alliance(43) was created in promoting disaggregation of the Radio Access Network through open network interfaces and access to the Radio network data through its Radio Intelligent Controller (RIC). It is noted that a cellular network cost is dominated by the selection of its RAN supply chain. Further activities such supplier chain diversification(44) in UK has paved the way for further research and development to bring about a commercial solution based on future telecom networks with open interfaces.

While starting this open radio networks ecosystem has not been easy, it is now gaining traction. This approach is working with a significant number of new companies releasing products in telecom networks. The businesses range from new start-ups to established businesses in adjacent market sectors. The MNO are encouraging this by outlining targets for Open RAN deployments across their networks. Such a move helps to create new market entrants and indicate further credibility in Open RAN in the 6G era. This is the fundamental rationale for our Recommendation 2 of the 'Open6G' testbed.

The open RAN ecosystem, use cases and business cases are gaining momentum, which is enabling an acceleration of technology development including RIC, xApps and rApps.

(43) Open RAN Alliance
(44) Telecoms Diversification Taskforce: findings and report

RIC, x-apps, r-apps are perfect bridges to the future for currently prevalent monolith and upcoming disaggregated RAN systems. The O-RAN Alliance, founded by Vodafone, DT, Orange, Telefonica, and TIM, have defined an architecture which specifies individual RAN components which can operate independently. One key element is well-defined interfaces between the RAN components. As an example, the open fronthaul interface has been introduced between the network and the radio head, which has stimulated the growth in independent specialist radio head companies.

The emergence of specialised system integrators, with efforts to streamline system integration developments, though, are set to redefine the future of AI integration in the telecom industry.

Deployment starts with setting up and putting into operation the telecoms network, and then continues into the operational phase including maintenance and optimisation, evolving the network to changing demands. To set up the network, the components from the architecture are assembled and tested together, a process known as system integration.

The disaggregated open RAN market has started to establish credibility, though it will take time to see if new entrants can persist. While disaggregation can drive TCO benefits it may introduce an additional system integration headache, though these are being mitigated in a variety of ways. Specialist system integrators are emerging, such as Rakuten Symphony or Aspire Technologies, who have skills, tools, and experience to identify and resolve issues in a systematic way, resulting in a robust network.

Some MNOs are building similar capability, recognising the value of these activities. There is much activity in industry bodies to provide pre-integrated solutions, thus sharing the system integration across the ecosystem, rather than the MNO. This works well as the equipment providers are very motivated to integrate with other vendors to ensure their products have high performance in real networks. For example, the Telecom Infrastructure Project (TIP) tests a set of components that have been integrated in defined end-to-end scenarios and issues badges to indicate successful completion of the integration.

The MNOs have stated their intentions and are in the early stages of making deployments. New equipment vendors in telecom and the associated AI technology have created products. A credible system integration certification system accelerates deployments of networks made up from several network equipment vendors. All the pieces are in place for new vendors to win new business with the MNOs.

The evolving network architectures collectively influence the way AI is integrated into the Telco network in the future, as well as the integration of the network itself. The emergence of specialised system integrators, with efforts to streamline system integration and developments, are set to redefine the future of AI integration in the telecom industry.

2.1.2.3/ Cloudification

Telecom operators are increasingly exploring collaboration with hyperscale cloud providers to expand their revenue streams. Hyperscalers offer cloud infrastructure, compute, storage, and networking resources, which supports many business functions and the virtualisation of the networks themselves, enabling services such as Platform-as-a-Service (PaaS), Software-as-a-Service (SaaS) and Infrastructure-asa-Service (IaaS).

The MNOs offer cloud or hybrid cloud as services to their own customer base. Carriers can benefit from migrating suitable applications and systems to either public or private cloud environments, including billing systems and Business Support System (BSS). This involves distinguishing legacy systems that pose migration challenges and embracing modern BSS and partner monetization platforms to unlock additional revenue streams.

Hyperscalers are increasing their involvement in telecom networks, offering solutions not just in enterprise IT environment but also in the core network components where they offer solutions to include the core network. There has been a gradual convergence between telecom operators and Hyperscalers, as they recognise opportunities to deliver higher-value, vertical-specific solutions in realms like SaaS, PaaS, and Network-as-a-Service (NaaS). With the ongoing cloudification and network disaggregation, operators are increasingly equipped to offer tailored solutions to specific industries and enterprise clients, expanding their business beyond traditional connectivity services.

Operations Support Systems (OSS) and BSS are critical elements of telecoms networks. OSS is a collection of software applications enabling providers to monitor, analyse and manage telecom networks including activities such as network inventory, service provisioning and network planning. BSS is software which helps telecom organisations handle the customer facing activities such as billing, subscriptions, and Customer relationship management (CRM). OSS and BSS, being substantial and intricate software systems, offer a natural entry point into this sector, requiring relatively less domain knowledge of telecom systems to build and implement. However, the rapid proliferation of network virtualization has opened up new opportunities to offer supplementary products and foster partnerships. Hyperscale cloud providers have joined forces with established core network vendors or have developed/acquired their own core network solutions, progressively delving into specialised domains within the telecommunications landscape. Hence, Cloud Native Telco is developing fast and there are some significant integration barriers from the BSS and OSS.

While the results of these inroads in the sector are difficult to foresee, it is clear there is scope for significant disruption. Considering video streaming as an example, where Over The Top (OTT) services such as Netflix and Amazon Prime Video have exploded in little over a decade. Their subscriber base has grown massively in this time, and they now create increasing amounts of original content, to some extent displacing the roles of TV broadcasters. They have captured the rights to some of the largest film brands such as Star Wars and James Bond, which is a significant disruption to the movie studio ecosystem. It is unlikely these were foreseen when the video streaming services were nascent. In the same way it is hard to predict what the disruptions may be. However, with i) access to large scale data sets, ii) the relatively mature AI platforms that accelerate deployments of new models and iii) integrated training pipelines, and iv) the acquisition of wireless and telecoms domain knowledge; it becomes clear that the emerging trends of mitigating Telco load, services, and network functions to the cloud could disrupt the industry in the near future.

2.1.2.4/ Distributed Computing

Telecom is a distributed system and there are opportunities to create multi-disciplinary solutions across the communication and computation platform.

Centralised AI refers to functions that are typically characterised by non-critical time constraints and input/output bandwidth requirements allowing them to be deployed anywhere in the operators' network. For convenience, these are likely to be co-located in a single location (or a very small number of locations to allow for network resilience). The primary challenge for these platforms is the scaling up the performance of an elastic, shared AI training and inference compute resource while managing cost and power consumption.

Distributed AI refers to the distribution of training and/or inference functionality among multiple interconnected computing resources that are not co-located as a single, centralised computing system. For distributed AI such as Federated Learning, training and decision-making are distributed across various devices or servers, which can be located in different physical locations or interconnected through a network. Access networks by their very nature fall in this category.

The effectiveness of AI in a network depends on access to the right data and the ability to act in a timely manner upon it, calling for functions, and in particular, real-time inference to be performed locally to where the data is collected, with the resulting output and consequent action are required to meet latency requirements. This also avoids the bandwidth and energy costs of moving large amounts of data around the network.

We note that challenges exist for AI deployment in a distributed manner. For example, coordinating and transmitting data between distributed nodes can lead to significant communication overhead, which may become a bottleneck in distributed AI systems, especially when dealing with large datasets. In addition, inconsistencies or delays in data synchronisation can negatively impact the accuracy and performance of AI models. Ensuring that all distributed nodes have access to the same and up-to-date data can be challenging. As the number of distributed nodes increases, managing and scaling the system becomes more complex.

2.2/ Infrastructure

2.2.1/ Landscape

This remains a key part for integration, Infrastructure which is essentially the platforms and tools, are pivotal for telecoms AI integration. In this paper, we use the term "platforms" to refer to the computing platforms, which include both the hardware and the closely associated firmware and software. These platforms are necessary for both training and deploying inference in networks.

The following platform composition is assumed and highlight areas within the network infrastructure where innovation will be required to achieve a native-AI network, bearing in mind the discussion on Distributed Computing in the previous section:

Networks of Equipment, that consist of geographically dispersed equipment that collaboratively coordinates its functionalities.

Equipment, such as;

1/ Centralised Servers (COTS – Commercial Off-The-Shelf), that utilises AI acceleration for both training and inference, typically via plugin compute acceleration cards.

2/ “Edge” Equipment that facilitates training and embedded inference closer to data sources – likely to be composed of COTS servers with plugin acceleration as above.

3/ “Far Edge” Equipment that facilitates embedded inference closer to data sources either due to latency critical performance or to reduce the volume of data movement across the network - items such as base stations. IoT devices connected to the network such as CCTV cameras containing inference are considered out of scope in this section.

Semiconductors, such as GPUs from Nvidia, AMD, and Intel; AI-specific hardware such as Nvidia's DGX(45), Google's TPU(46), Graphcore IPU(47); Dedicated inference devices such as XMOS targeted at IoT applications(48); and Silicon IP for System-on-chip designs(49): such as these from Synopsys(50), Imagination Technologies(51).

Hyperscalers, that offer cloud infrastructure, compute, storage, and networking resources, which supports many business functions and the virtualisation of the networks themselves.

The following table overviews the actors in the infrastructure space. We gave examples of actors across the globe, some of which have headquarters in the UK.

Table 1 – Types of actors currently active in infrastructure

Actors	**Status**	**Examples (non-exhaustive)**
Mobile Network Operators (MNO)	Ever increasing data demands and reducing ARPU are placing pressures on investment	Vodafone, Deutsche Telecom, EE
System integrators	Some MNO and network equipment vendors are acting as system integrators. There are specialist independent System Integrators too.	Rakuten, Vodafone, Aspire Technology
Wireless technology specialists	Developing bespoke high value use cases	Cambridge Consultants, REPLY, Accenture, Axis
Hyperscalers	Looking to enter the market. Virtualisation, network in a box.	IBM, Google, AWS, Azure
Virtualisation specialists	Network services with more flexibility and scalability enabled by AI.	RedHat, Wind River, VMware
Specialist communication networks	World leading specialism. May not have scale or skills to apply AI.	OneWeb, Ocado
network equipment vendor	Dominant market share on MBB Growing private network	Ericsson, Nokia, Samsung, Huawei, ZTE
network equipment vendor adjacent sectors	Creating RIC platform and extending AI towards RAN	Cisco, Juniper
Silicon and Silicon IP	Designing silicon for networks	ARM, Picocom, Intel, AccelerComm, NVIDIA

(45) NVidia DGX Platform
(46) Accelerate AI development with Google Cloud TPUs
(47) Graphcore Intelligence Processing Unit
(48) XMos Platform
(49) ARM 'Immortalis' Flagship Graphics Processing Unit (GPU)
(50) Synopsys.ai Full-Stack AI-Driven EDA Suite
(51) Imagination IMG DXD

2.2.1/ Emerging Trends

2.2.2.1/ High Performance Computation

The need for high-performance computing to support the widespread adoption of AI in future networks is evident. Lack of own computing infrastructure, and chipset vendors in the UK poses a potential risk, as well as impeding the country's ability to seize the opportunities that AI offers.

We recognise the need for high-performance computing to support the widespread use of AI in a future network. It is well known that the training of AI models requires immense computational power, including to process and analyse vast datasets. As AI applications grow in complexity and scale, the demand for high-performance computing increases significantly, leading to 100 times increase on hardware cost every two years(52).

High-performance computing infrastructure, often equipped with specialised hardware like GPUs or TPUs, can significantly accelerate the AI tasks, enabling quicker model training, hence more viable for AI model deployment. Having the infrastructure not only accelerates AI tasks but also enables the development of more sophisticated, accurate, and innovative AI models. As AI continues to advance and become widespread in the Telco network, the demand in Telco for optimised and scalable compute infrastructure becomes increasingly pivotal. Scalable, high-performance compute, that are optimised for low power, low cost AI, are desired.

While the UK has made significant investments in world-class supercomputer centres, such as at the Edinburgh Parallel Computing Centre(53) and upcoming Supercomputing Centre at Bristol(54), there are concerns about their ability to keep their technology updated with the fast moving advanced computing technologies(55). According to the same article, it is possible to purchase or rent computation resources and shop from existing computation powerhouse players in the US, e.g., Google, AWS, and Microsoft, therefore allowing organisations to tap into super computing power without the significant upfront investment required to build and maintain their supercomputers. However, relying solely on rented supercomputing platforms can lead to significant drawbacks, such as:

(52) OpenAI - Open AI and Compute
(53) EPCC - Who we are
(54) University of Bristol - Unprecedented £225m investment to create UK's most powerful supercomputer in Bristol
(55) The Economist - How to make Britain's AI dreams reality

1. reliance on foreign clouds leading to complexities in maintaining the resilience of telecom networks, as varying geopolitical landscapes can indirectly influence the stability and reliability of these services;
2. data privacy and security concerns arising from sensitive information and advanced research being stored or processed on servers possibly located in other countries, subjecting it to different legal regulations and security standards (raising issues related to compliance, confidentiality, and intellectual property protection); and
3. reduced control over computing resources and services, potentially affecting performance, availability, and customisation options.

We note that in addition to improving the compute performance, there are also methods for the development of embedded AI models and improving the computational complexity of the training, inference, and inference latency, through model distilling and model pruning. It is expected that more capable AI architecture in the future will enable even more versatile development of AI models in telecom.

2.2.2.2/ Optimising AI Workloads across the infrastructure

Opportunities are arising for innovation in low power, low-cost AI with more computational efficiency. However, it is also crucial to recognise the need of advancing network infrastructure to accommodate efficient operation and deployment of AI in the next generation network.

While much attention has been dedicated to the use of AI within network operations, it's equally important to address the growing significance of optimising AI workloads throughout the entire network infrastructure, to allow efficient deployment and management of AI training and inferences across the terminals, edge, and cloud. Energy footprint of AI systems, especially those relying on GPU clusters, remains a concern, especially taking into account of the sustainability goal in the ITU-R framework for IMT-2030(56). Further exploration on sustainability particularly related to AI can be found in Section 3.2 Sustainability. To mitigate this, emerging technologies, such as edge computing, are gaining traction to allow the distribution of computational tasks with energy and computational efficiency in mind. Federated Learning and Transfer Learning are the other examples that allow for real-time, localised processing of raw data and AI tasks, effectively reducing the need for data transport over backhaul connections.

(56) IMT-2030 Framework_WP 5D Management Team.pdf (itu.int)

Opportunities are arising for innovation in low power, low-cost AI with more computational efficiency. We note, however, that innovative general-purpose AI algorithms must navigate the intricacies of network infrastructure in order to be effective. For example, the need for high-speed throughput to deal with the AI workloads and data flows may clash with the limitation of existing networks (such as Gigabit Ethernet used in Data Centres), which can become a bottleneck since they may not scale efficiently. Different congestion events may have an impact on training and inference. As a result, while we develop innovations around AI algorithms to ensure that AI systems are not only high-performing but also efficiently and harmoniously integrated into the existing infrastructure, we must also advance the network infrastructure to accommodate the efficient operation and deployment of AI models and manage AI workloads, the latter we refer to as 'Network for AI'.

2.2.2.3/ AI Training and Inference

Both training and inference rely on a highly constrained form of computation due to the nature of most machine learning models. This is in contrast to the general-purpose compute that a processor in a server or a base station might normally perform.

The computation resources required by training and inference are driven by different needs. Training of most types of models is a highly iterative process to optimise the model parameters for best inference accuracy and typically performed "off-line", i.e. aside from the real-time operation of the deployed model. This process has very high computation demands and whilst there may not be specific time constraints on training time, huge compute resources are often required to perform this task in a practical timescale. The platforms used are often highly scalable(57) server/cloud-based, so that the compute resources can be "dialled up" to complete training in a usable time frame.

(57) J. Hoffmann et al., 'Training Compute-Optimal Large Language Models'. Mar. 29, 2022

Inference tasks – estimating an output based on inputs using a previously trained model - will typically have performance requirements in terms of the number of inferences per second and the delay or latency from receiving inputs to providing an inferred output. Across a telecoms network there will be a large range of these requirements from the huge non-real-time LLMs to embedded more lightweight, real-time functions in wireless base stations. See discussion on "Baseband Semiconductor issues" in the Future Capability Paper Wireless Networking.

Although the majority of the computational resources are needed at the training stage, both training and inference rely on a highly constrained form of computation due to the nature of most machine learning models. This is in contrast to the general-purpose compute that a laptop or server might normally perform. The particular form of computation (matrix operations in linear algebra) is well suited to GPUs originally designed for PCs and workstations for graphics design, video editing and gaming applications.

2.3/ Data

There's no doubt that the Telco industry will be AI-driven, integrating machine learning into all system and business levels, from the radio aspects to the higher layers addressing intelligent network function placement, configuration and optimisation, service provision and assurance, network security, and resilience.

Data is essential in driving the progress of AI in the network. To effectively train and enhance AI models, a substantial volume of high-quality data is essential. The Telco network has an abundant data source with data repositories distributed across billing, customer care, network management and other network functions (RAN, Core, Transport, Edge, Cloud, and service). Significant standardisation and the development of data framework requirements to facilitate machine learning in future networks have been undertaken by organisations such as ITU(58), TMF(59), NGMN(60), 3GPP(61). Details of some of the data requirements, framework, and standardisation can be found in Annex B. Unfortunately, the existence of multiple standards and organisations addressing data issues also reflects the current fragmentation within the telecommunications industry, and persistent practical challenges related to data remain.

2.3.1/ State of the Art

2.3.1.1/ Data Accessibility

There is a critical need to streamline data acquisition and management, overcoming challenges associated with fragmented data sources, lack of standard interfaces, and data quality issues.

We believe in order to harness the full potential of AI in telecom networks, data acquisition and generation in the domain will be of the utmost importance. In the telecom industry, sourcing of usable data often involves navigating through disparate databases, logs, legacy systems, and even the prevalence of data stored in spreadsheets.

(58) ITU Framework for data handling to enable machine learning in future networks including IMT-2020
(59) TM Forum AI Governance Toolkit
(60) Automation and Autonomous System Architecture Framework
(61) 3GPP TS 22.261 “Service requirements for the 5G system; Stage 1” and 3GPP TR 37.817

This fragmented data landscape can hinder progress and make data usage cumbersome. Accessing data relevant to a specific use case is often further complicated by lack of standard interfaces and APIs or limited vendor documentation that explains how to query and subscribe to the appropriate data sources.

Not least, data may be noisy, incomplete, and unstructured, which complicates both neural model training and inference. Cost savings in the context of AI adoption in the telecommunications industry can be achieved through various means. One of the most significant avenues for savings is by lowering the barrier for AI model training. Historically, acquiring and processing data has posed a formidable challenge, both in terms of time and resources. By streamlining this process and making data more accessible, Telco companies can realise substantial cost reductions for AI model development and deployment. Hence, optimising data collection, post-processing, warehousing, and storage is essential to harness the full potential of AI in telecommunications.

2.3.1.2/ Data Utility & Privacy

Telco networks have abundant data sources, yet the sensitivity of this data has posed challenges for its accessibility and utilisation.

Opportunities exist to develop neural networks that allow data owners to create synthetic datasets from raw data, enabling the generation of realistic network patterns while preserving privacy, facilitating the development of AI solutions without compromising sensitive information.

While abundant data sources can fuel the development of innovative AI/ML solutions to tackle complex problems in the telecoms space, including accurate traffic classification for network slicing, virtualised RAN resources control, and more, the availability of rich dataset is currently limited. This is because such data frequently carries sensitive information, both from a user privacy perspective and from a commercial standpoint.

Data anonymisation techniques such as differential privacy(62) and k-anonymity(63) can help hide user-specific information at a utility cost. On the other hand, obfuscating network level information that reflects e.g., network topology, coverage areas, and routing paths, without compromising features that are key to the training of AI models is technically challenging. We also note that although privacy concerns can be addressed to some extent by anonymisation, there is still a risk of compromising privacy, by combining disparate telco data sets with other external datasets and processing with AI to re-identify individuals.

We believe opportunities exist to design neural networks that can be trained with raw data by the data owners to produce synthetic data sets that can capture realistic patterns of network usage at different times of the day, traffic profiles in geographic areas with distinctive clutter and population densities, and mixes of device types. These would be subsequently used by third parties and independent software vendors to design AI solutions for specific problems, without accessing sensitive information.

2.3.1.3/ Data Imbalance

Datasets available in telecom networks are frequently imbalanced. For instance, the volume of legitimate user traffic is far larger than that of illicit activity such as Denial of Service (DoS) attacks. Training AI models with such imbalanced datasets poses the risk of models learning superficially and being unable to learn reliable decision boundaries needed to identify specific types of traffic and events.

The impact of Telco data imbalance on AI is addressed further in Section 3.4.2 AI Ethics. From the technology perspective, to circumvent this problem, it is useful to augment datasets used for training with synthetically generated samples that increase the variability of non-essential features, which improves data heterogeneity and helps models avoid becoming trapped in local optima. Oversampling of data types that are less represented further helps tackling this problem.

(62) Differential Privacy in Telco Big Data Platform
(63) GLOVE: Towards Privacy-Preserving Publishing of Record-Level-Truthful Mobile Phone Trajectories

Additional abstract labelling of item types (e.g., different type of networking attacks) can help prevent overfitting by grouping similar types but with subtle differences among them into the same class. Further auto-annotation by means of unsupervised models that learn baselines of network performance indicators can enrich training datasets and enable generation of synthetic samples which help models explore corner cases that may not have been captured in the original data, but which may occur in production.

2.3.1.4/ Data Security, Vulnerabilities and Risks

As noted previously, datasets that are in compliance with national and international rules of data legislation need to come to the fore, ensuring anonymised customer and network data. In the meantime, these datasets must also support procedures to train and validate AI/ML algorithms beyond static pattern recognition and are adaptable to the dynamic nature of networks that are constantly changing environments, changing number of users, and changing topology.

Ensuring data cleanliness and integrity is essential for the optimal functioning of AI in telecommunications and for maintaining the security and resilience of the entire telco value chain.

In the context of telecommunication systems where AI models are adopted throughout the value chain, data cleanliness refers to the quality, accuracy, and reliability of the datasets used to train and operate AI algorithms. Clean data is up-to-date and free from errors, inconsistencies, and inaccuracies. Data cleanliness directly affects the efficacy of AI models integrated throughout the value chain in telecommunication systems from air interface to core network, in tasks such as interference management, resource allocation, predictive maintenance, network optimisation, customer services, and fraud detection.

In this context, data integrity also ensures that data remains accurate and unaltered throughout its lifecycle. In the context of network security, data integrity safeguards against unauthorised modifications, ensuring that the information flowing through the telecommunication network is trustworthy. AI algorithms, relying on the integrity of data, make critical decisions affecting network operations, security protocols, and responses to potential threats.

Data

The telecommunication value chain is highly interconnected, and any compromise in data integrity and cleanliness can have cascading effects. In addition to a faulty data pipeline, this can be done through adversarial attacks on the AI models using data poisoning hence posing risks to the efficient operation of telecommunication systems. Examples of such risks include:

- Network Vulnerabilities: Compromised datasets could lead to inaccuracies in predicting network vulnerabilities. AI models trained on such data might fail to identify potential security risks, leaving the network exposed to threats.
- Service Disruptions: Inaccurate data regarding network health and performance can trigger erroneous responses. AI algorithms might make decisions based on flawed insights, potentially leading to service disruptions or degraded performance.
- Misconfigurations: Maliciously edited datasets could result in misconfigurations in security protocols. AI algorithms, relying on tampered data, may implement incorrect security measures, creating loopholes for exploitation.
- Unauthorised Access: Corrupted datasets might impact the accuracy of user authentication models. This can lead to unauthorised access, posing a significant threat to the confidentiality and integrity of user data.
- Data leaks: AI algorithms might make decisions based on compromised datasets, potentially leading to leaking sensitive network or customer information.

We believe in order to mitigate these risks, telecommunication systems must implement robust data validation, encryption, and monitoring mechanisms. Regular audits of AI models, data pipelines, and datasets, coupled with stringent cybersecurity measures, help maintain data cleanliness and uphold data integrity.

We understand that there are vulnerabilities and risks associated with data management. Adversaries may modify the data by either manipulating existing inputs or adding corrupt instances to generate a falsified AI/ML model; this will have an implication on AI/ML accuracy. Adversaries may also target the model parameters directly by manipulating the learning rules which affect the computed local model parameter.

Further details on Data Security will be covered in the Security EWG.

2.3.2/ Emerging Trends

2.3.2.1/ Data Exposure and Monetisation

Leveraging the Telco cloud for data-driven transformation offers new revenue opportunities for Telco but requires addressing challenges such as immature business models and data security concerns.

Provided that security and privacy implications can be addressed, leveraging the Telco cloud for data storage, processing, analysis, and monetisation presents a compelling business driver for Data as a Service (DaaS). Operators face considerable expenses in managing and maintaining massive data processing and storage infrastructures.

The insights obtained from these data are often consistent across various networks. By facilitating data sharing and analysis across networks, among different operators, and with third-party entities, Telco companies can realise key advantages, such as optimising network maintenance, where shared data and analysis enable more efficient troubleshooting and proactive identification of potential issues, resulting in improved network reliability and reduced operational costs.

The transformation of Telco companies into providers of data-driven solutions becomes increasingly feasible through collaborative data sharing. This shift allows Telcos to create innovative products and services that leverage the wealth of data at their disposal, not only addresses the challenge of cost-effective data management, but also empowers Telco companies to enhance network performance, improve customer retention, and capitalise on data-driven solutions to drive business growth. With data collaboration and shared insights, Telco operators can gain access to data from other networks, such as private networks dedicated to specific customer types. This access opens up new possibilities for offering tailored services and innovative solutions. It enables Telco operators to tap into a broader pool of data to improve their offerings and meet the unique needs of different customer segments.

A transformative aspect of AI adoption in the telecommunications industry is the potential for Telco companies to evolve into Techcos. By offering a comprehensive bundle of data and AI-driven solutions, Telco operators can diversify their services and revenue streams. This transformation allows them to become more than mere data carriers; they can now provide value-added services that leverage data and AI to address a variety of needs, from network optimisation to customer experience enhancement.

One of the challenges in realising data monetisation in Telco is the absence of mature business models. In addition, we highlight here that as CSPs delve deeper into AI and data analytics, they must grapple with significant data security and privacy concerns. Ensuring the protection of sensitive customer data and complying with regulations like GDPR and CCPA is paramount.

2.3.2.2/ Enabling Unified Data Accessibility

Enabling unified, secure data access and sharing across the telecommunications industry is vital for fostering a thriving ecosystem, not only within the telecom sector but also between Telcos and their vertical partners.

Establishing a robust data governance framework is another challenge to realise the AI-driven telecommunication landscape. This includes determining data ownership, usage rights, and data sharing protocols across the network. In a complex ecosystem involving multiple stakeholders, including third-party providers, establishing a clear framework for data governance can be a complex task.

Data are stored and shared in a trustworthy environment and within one or multiple ecosystems has become the backbone of innovation, not only within the telecom sector but also between Telcos and their vertical partners. Enabling unified, secure data access and sharing across the telecommunications industry is vital for fostering a thriving ecosystem.

Unified data accessibility initiatives are taking place on a global scale. For instance, in January 2021, the Gaia-X European Association for Data and Cloud AISBL (French: association internationale sans but lucrative), was founded to develop the technical framework to enable the concept of a 'Data Space'(64). It represents a trusted data relationship among partners who share high-level standards and guidelines for data storage and exchange within one or multiple vertical ecosystems. Verticals such as Health, Energy, Finance, and Insurance have already adopted data spaces. A key element of the data space concept is decentralised data storage, with data transferred through semantic interoperability(65) only when needed. Data in the Gaia-X Data Spaces context is kept exclusively by the association's members. Data sovereignty and trust are essential for data spaces to work and support relationships between participants. In this reference, the term "Semantic Interoperability" is defined as "the ability to automatically interpret the information exchanged between two or more parties."

(64) Gaia-X fosters data exchange and facilitates interoperability between data spaces.
(65) Gaia-X: Compliance as Code

2.3.2.3/ Catalysing the Data Ecosystem

Opportunities are arising in Telco not only for monetising the abundant network data but also for actively catalysing the broader data ecosystem in collaboration with its partners.

Telcos are also leveraging their own vast data sources and connectivity capabilities to access third party data, to provide unique insights to enterprises, marking a shift towards data monetisation. Range and potential value of data monetisation use cases that Telcos could develop have been identified(66). Geolocation data and associated products which anonymise and integrate data into Telco products accounts for 80% of total financial value from standalone data and analytics products(67). Various industries, including tourism and government, have the opportunity to harness this data to identify "people hotspots" and can help them decide where to place certain technologies e.g., CCTV, smart lighting, cafes (see section 3.1 Economy for further details).

Cost, the complexity of existing systems and rigid organisational structures are the three leading reasons why CSPs' progress in transforming their monetisation systems is being inhibited(68).

Given the sensitivity of data and the evolving landscape of geo-politics, the UK is presented with a unique opportunity to take a leading role in establishing a data initiative that ensures both security and open access to Telco data. By establishing robust standards, guidelines, and regulatory frameworks, the UK can foster an environment where trusted partners can securely collaborate and access data, enhancing innovation and data-driven solutions within the telecommunications sector and between Telco and its partners. This initiative not only bolsters data security but also positions the UK as a leader in responsible data sharing and utilisation, thereby attracting global partners and stakeholders to engage in secure and ethical data practices.

(66) Telco data monetisation: What is it worth?
(67) How telcos could build data exchange marketplaces
(68) Analysys Mason: The Future Of Telco Monetisation Systems: An Evolutionary Revolution, John Abraham & Andy He

2.4/ Network Testing with AI

2.4.1/ State of the art

An important complement to the operation of the networks is how we test, monitor, and assure them. AI is playing an increasingly important role here. Here the focus is on how we use AI for testing networks. Testing AI in networks is an important subset of the broader scope, and key to the successful assurance and deployment of AI in the network.

The various stages of the network lifecycle are considered here. More detailed background of network testing is given in Annex E as background information for interested readers. As is the testing of components and characteristics of the network implemented with traditional explicitly programmed or engineered solutions, the communication service providers who deploy the networks will often perform testing in the lab prior to deployment. After the lab testing stage, the networks are deployed, which requires testing for the most satisfactory outcomes. This deployment testing also maps to the network expansion and upgrade operations that inevitably take place. Once the network is operational, the testing includes the monitoring and data collection along with the assurance that ensure that service is delivered without interruption where possible and detects impairment where problems do arise, along with minimising the impact on the subscribers of the service quality being below what is desirable.

The testing of operational networks has traditionally been driven directly or indirectly on the performance of the network as a whole, and whether users are able to establish a connection to the network, retain that connection, and consume the services delivered over that network with sufficient quality and without excessive use of resources. Where this is not the case, the root causes fall into broad categories. Examples of root causes include physical impairments to the infrastructure including network functions and components along with connectivity between them is one cause. Insufficient capacity leading to congestion, in the network functions and connectivity links, is another class of root cause. Changing behaviour of subscribers is another root cause. In cellular radio networks, interference can cause problems if not managed. In some cases, there may be functional problems in the infrastructure, for example misconfigurations or software bugs that mean the components operate sub-optimally or contrary to specifications in some corner cases. The extensive lab testing typically performed means that these cases are generally rare.

AI is expected to improve network fault detection, root cause analysis and resolution. Network fault detection is applicable at all stages of the network lifecycle from lab, through integration, deployment, and to the testing of the live operational network. A highly experienced human can often identify and resolve network issues based on experience, for example through simple thresholding of KPIs, however this is often time-consuming, tedious, and highly reactive. More sophisticated anomaly detection or classification agents can help expedite the process of determining and resolving the underlying root cause, and subsequently provide recommendations to a human operator or autonomously fix the configuration itself. Such an AI-driven and autonomous testing process significantly enhances the testing capabilities and speed of the network, allowing more discerning and lower cost testing with less infrastructure and personnel resources.

2.4.2/ Emerging Trends

2.4.2.1/ Impact of AI on Network Testing

Test process automation is emerging in the industry, and it can be further improved with AI. However, the introduction of AI may cause unpredictable behaviour, which disrupts the network test industry.

As networks are deployed or problems are being fixed, engineers and technicians often follow steps to validate installations or troubleshoot problems. This will include using equipment to make measurements and collect data about the fixed and wireless aspects of the network; the access, transport, and core; also at various network layers from the physical to the application. Based on these measurements, various decision points are reached that direct the line of enquiry until a root cause is reached or a successful test is achieved. This test process automation is starting to emerge in the industry and is something that lends itself to enhancement with AI. Automated test case selection is an enabler for this. Diagnosis of a problem and identification of the most effective resolution typically requires a number of measurements to be collected and tests to be performed. Using AI to drive the decision process for these measurements and tests can in principle improve the accuracy of the diagnostics and reduce the time and cost needed to reach these diagnostics.

The transition to AI in networks leads to another potential class of root causes. Where ML models underpin parts of the functionality, these models mean that the components they are part of are no longer explicitly programmed and so are not deterministic in their behaviour. If models are insufficiently trained, stale or poorly architected then they may become the root cause of undesirable behaviour of the system as a whole, leading to the subscriber-impacting issues mentioned above. This is a disruption for the network test industry that can be potentially capitalised upon by UK industry.

The group note that testing is an endeavour that often involves classification of phenomena, where in the context of testing, ML-based classification at the moment needs proper human supervision and interpretation of the results that are dependent to the test case. For example, when testing is a case of classification it is generally desired to achieve as few false negatives and false positives as possible. Optimising network tests is not simply a case of maximising precision and minimising false negatives. Depending on what is tested, it may be that one is preferred over the other. For example, consider a high value network slice with strict QoS requirements. If an impairment arises that threatens the SLAs, associated punitive financial penalties would be triggered. In this case, a false negative on classifying that impairment would have serious financial consequences, while a false positive would simply result in some investigation to rule out a threat to the SLA. In this case it is most important that the recall is high, meaning few if any false negatives. While it is also desirable that the precision is high, this is less important than having fewer false negatives.

Since ML models depend on data, the nature of the data is important. Measurements and counters have long been used in telecom networks to drive understanding of the network, including its performance and pathologies. This is largely a qualitative endeavour which means that the exact nature of the data can change without dramatic impact on the network. Issues can arise if the data that have traditionally been used for generation of KPIs are then used for model training and inference, If the way that the data are generated changes, either through a defect or by design, the impact on the models that depend on the data can be serious and can lead to poor quality inference and resultant impact on performance. Hence the testing of the data generated by the network becomes more important as the way the data is used changes to encompass ML.

2.4.2.2/ Digital Twin Network - an evolution on testing

Leveraging a network digital twin for AI and closed-loop based testing can focus not only on realistic test cases, but also on representative test cases that are closer to what might be encountered in the real world, when deployed on a specific network.

A problem that manifests in an operationally deployed network means that the systems and solutions for testing the network and the processes for diagnosis and resolution are exercised in response to the problem. Traditional lab testing of the network relies heavily on simulation that tends to focus on creating realistic scenarios, perhaps designed by engineers and other experts, to exercise the communication systems in a wide variety of ways.

The development of the digital twin concept focuses on creating duplicated network entities and scenarios that reflect the real network. This allows bidirectional gathering and exchanging of the data between the digital and the real-world networks, for the twin to perform any AI-based analysis and proactive detection and prevention of potential network faults. In addition, a digital presentation of the network allows operators to run and test AI deployment in the twin before deploying to the real network. This means AI algorithms can be fully tested in a safe environment within the digital twin, without bringing adverse performance impact to the operational network, despite the 'black-box' nature of the AI algorithms. This enhances AI assurance and operators' experience and confidence in AI deployment.

There are activities emerging in the industry that envision classes of next generation services. These will depend on sufficient quality of experience and uninterrupted quality of service. More transient network impairments will have more serious impacts on the consumers of these services in contrast to more traditional services. Establishing that the network is successfully delivering the quality of service, and in cases where it is not, identifying the root cause of the problem, is expected to require more sophisticated monitoring solutions, able to resolve performance problems at more granular spatial and temporal scales. More granularity in telemetry risks a data deluge and the associated costs of management of these data. Avoidance of such problems will likely drive the use of AI to perform more distributed detection and classification of problems for example.

2.5/ Services and Business

In addition to the network operation, AI has also brought about a significant shift on Telco service provision, business operations and business models in fundamental ways.

2.5.1/ State of the Art

2.5.1.1/ Autonomous Networks

Traditional OSS and BSS systems focus on automation of processes and workflows decided at design time. Implementations run process steps in accordance with the processes and logic decisions determined at design time.

Autonomous networks and systems are a novel OSS, BSS and network integration approach investigated within 3GPP IETF, IEEE and TM Forum. These studies are about autonomy where authority has been delegated between systems to make decisions to achieve defined outcomes.

The TM Forum integration approach is based on Autonomous Domains (black boxes that encapsulate current OSS, BSS, and Network/resource function) where the communication among domains is through Intent management interfaces that delegate responsibility from one Autonomous Domain to another. Intents describe the outcome required for delegation not the process to be followed within an Autonomous Domain.

This approach enables a few innovations in network design such as:

1. decoupling of the internal design of Autonomous Domains from the evolution of Intent interfaces;
2. introduction of AI machine learning using large language or domain specific models within an Autonomous Domain which set the scope of their decision making (policy, guardrails);
3. The use of AI to manage closed loop automation using evolved current OSS, BSS, and network system where AI adapts at run time the decision making based on inputs to the domain and changing intents; and
4. The use of multiple Closed loop automation operating on different time scales supporting the models such as that proposed in ETSI GANA Generic Autonomic Networking Architecture(69) for Cognitive Networking, and self-management of Networks and Services.

(69) ETSI GANA - Generic Autonomic Networking Architecture White Paper

2.5.1.2/ Intent Based Networking

Intent Based Networking (IBN) is an example of enabling technology to achieve AI-native networks. Ideally, an intent-based network can intelligently and autonomously manage the network operations and resource allocation without human intervention. IBN uses the following building blocks to realise intent: translation and validation, automation, state update, dynamic optimisation, and security. In a full deployment of IBN, the goal is to provide assurance and monitoring and have full life-cycle management intentions from administration level into the infrastructure. The vision of fully automated network management cannot be achieved without implementation of high-level intention and policy translation and configuration.

2.5.2/ Emerging Trends

2.5.2.1/ Telco Transformation empowered by AI

The convergence of AI, computing, and connectivity redefines the role of telecom networks not merely as providers of connectivity, but as versatile platforms that drive innovation and collaboration.

The integration of AI in the telecommunications sector has brought in a new era of business innovation, with profound implications for data and AI-driven automated operations that is revolutionise conventional business practices in Telco industry. For instance, tasks that were traditionally performed by human operators, such as monitoring network anomalies from behind dashboards, can now be effectively automated through advanced network automation. This not only leads to a reduction in operational costs but also enhances the precision and quality of data-driven decision-making, while mitigating the risk of error-prone operations.

AI-driven revolution is extending its influence into customer service, where the introduction of speech AI-based applications is altering the customer experience landscape. Agent assists, AI virtual assistants, and digital avatars are being deployed to enhance customer service, encourage self-service options, and significantly amplify overall customer satisfaction. These AI-powered applications are enabling telecom companies to deliver personalised and efficient service, effectively meeting the evolving demands of modern consumers. Emerging trends also include generative AI-powered chatbots for customer support and AI-driven content recommendation systems, both of which elevate customer engagement.

Generative AI has begun to get utilised in the telecom industry from 2023 with Generative AI-powered chatbots for customer support and AI-driven content recommendation systems, both of which elevate customer engagement(70). New partnerships to create innovations in this area are also emerging already with some key global operators announcing that they are jointly exploring creation of a telecom LLM to support conversational AI(71).

The convergence of AI, computing, and connectivity in the context of 6G is transforming the way mobile telecom services are offered to third parties. Telecom networks now serve as dynamic platforms that host data, intelligence, communication resources, and computational capabilities. The integration of AI facilitates the flexible and dynamic exposure of network capabilities and solutions 'as a service' to third parties, including AI and data capabilities. This empowers telecom companies to provide their infrastructure, resources and expertise to external partners and customers in an adaptable and scalable manner, often facilitated through open APIs. The departures from traditional telecommunications business models, characterised by rigid and static services, and redefines the role of telecom networks not merely as providers of connectivity, but as a platform that drives innovation and collaboration, ultimately shaping the future of telecommunication business models and eco systems.

2.5.2.2/ Telco Strategy Shift

CSPs are proactively investing in AI initiatives, fostering collaboration, and adapting their strategies to tap into the vast potential offered by AI.

As Telco companies embrace AI, their focus extends beyond enhancing core services to exploring new AI-powered applications and services that hold the promise of creating novel revenue streams. This forward-thinking approach has driven CSPs to strategically align themselves in the rapidly evolving tech landscape. For instance, SK Telecom (SKT) has unveiled its ambitious vision to transform into a global AI company, concentrating on three key pillars: AI Infrastructure, AI Transformation (AIX), and AI Service. By forging strategic partnerships and expanding its AI capabilities, SKT aims to solidify its global presence(72). Similarly, Telenor(73) has hired their new CTO who talked about their strategy of becoming an AI-first Telco in multiple and very different markets.

(70) ICMI - The Promise Of Generative AI: New, Flexible Customer Experiences
(71) Telecom Titans, Deutsche Telekom sees SKT, Anthropic do heavy lifting on multi-lingual LLMs, Ken Wieland
(72) SK Telecom announces AI Pyramid Strategy to become a global AI company
(73) Telenor's new CTO on becoming an AI-first telco, TelecomTV Article, Ray Le Maistre

In another move from Vodafone to become, what it calls a 'Techco' (technology company) rather than a Telco, in July 2022 built an AI Booster on its Google Cloud Platform (GCP); where in an interview Cornelia Schaurecker(74), global group director for big data and AI at Vodafone claimed:

"To maximise business value at pace and scale, our vision was to enable fast creation and horizontal/vertical scaling of use cases in an automated, standardised manner. To do this, 18 months ago we set out to build a next-generation AI/ML platform based on new Google technology, some of which hadn't even been announced yet... proud that AI Booster is truly taking off and went live in almost double the markets we had originally planned. Together, we've used the best possible ML Ops tools and created Vodafone's AI Booster platform to make data scientists' lives easier, maximise value and take co-creation and scaling of use cases globally to another level,"

AI empowers networks to dynamically adapt to diverse service demands by making real-time decisions about data collection, compute resource allocation, and AI model utilisation, enabling dynamic and optimal service provision for the CSPs – a path on the transformation of Telco to Techco.

On the business front, AI fuels predictive analytics, aiding in understanding customer behaviour and preferences for tailored services, thus increasing customer satisfaction and retention. Emerging trends also include generative AI-powered chatbots for customer support and AI-driven content recommendation systems, both of which elevate customer engagement.

In particular, Generative AI has surged onto the world stage with ChatGPT in 2022 and has captured the attention of consumers and industries worldwide including the Telco industry. Operators have reacted fast to embrace the new opportunities that can potentially be brought by generative AI (GenAI). Many believe that GenAI will enable new capabilities in Telco and enable use cases that are not currently served by existing AI applications and processes.(75,76,77,78)

(74) Vodafone builds on its Google Cloud relationship with AI Booster, TelecomTV Article, Ray Le Maistre
(75) Analysys Mason: Scenarios for GenAI and telecoms in 2033
(76) Telecoms.com, Samsung teases on-phone AI that will live translate phone calls, Andrew Wooden
(77) Ericsson: Four ways generative AI is set to transform the telecom industry
(78) Scenarios for GenAI and telecoms in 2033: GenAI has the potential to impact far more than customer service, November 2023, Tom Rebbeck

2.5.2.3/ Partnership and Collaboration

Create an environment that fosters partnerships among telecom, cloud, and AI companies, harness the collective expertise of these sectors to deliver more advanced and integrated solutions in future networks.

For several years, the telecom organisations worldwide have aspired to transform to "Techcos", a.k.a., the technology companies, as revenues and profitability have declined. One of the key differentiators between technology companies and telecoms companies is the investment in innovation. For example, technology companies invest around 11% of their 2022 revenue when compared to 2.7% of revenues by telecom companies(79). As such, the telecom industry has aspired to move up the value chain from only providing connectivity solutions to solutions that enable business transformation of their enterprise clients by combining connectivity, IoT solutions and AI(80). An essential need for effective implementation of AI-native across devices to Core continuum in the network can only be done through equal contributions of compute, communications, sensing, and intelligence providers.

As a result of Telco transformation to Techco and as service providers to other industries such as farming, manufactory, education, and tourism, third party customers can now harness the power of advanced network capabilities without the need for extensive infrastructure investments. This flexible 'as-a-service' model is fostering a new era of collaboration and innovation, empowering businesses to access cutting-edge technologies while telecom providers expand their service offerings to a broader audience. The convergence of these key elements promises a more dynamic, efficient, and inclusive telecommunications ecosystem.

While telecom companies have not traditionally prioritised collaboration with ecosystem partners, technology firms have embraced this practice for the last two decades. With the changing landscape of the telecommunications industry, it's crucial for CSPs to continue forming strategic partnerships to unlock the full potential of this transformative technology. Collaboration and synergy among various stakeholders are becoming essential to drive innovation, improve services, and maximise the benefits of emerging technologies.

(79) Andrew Sather. "R&D Spending as a Percentage of Revenue By Industry (S&P500)." March 8, 2021
(80) Telecoms' blind spot; Three key traits help leading telecom operators uncover innovative avenues for boosting revenue.

3/ Cross-Topic Subjects

3.1/ Economy

3.1.1/ Economic development

Innovations arising out of the convergence of AI and improved digital connectivity could contribute significantly to the UK economy.

The UK is on track to export £40 billion in Telecoms, Computer, and Information Services in 2023(81). Scaling and exporting innovative AI telecoms solutions to other markets could contribute significantly to the UK economy, but this will not happen by chance. The government will need to invest in the sector to develop an ecosystem and culture of innovation with a focus on both AI in telecoms and building and scaling businesses around this theme.

The economy will also benefit by attracting foreign direct investment in the sector through government support packages, including tax incentives and aid packages, for multinational corporations who opt to develop and commercialise their IP in the telecoms AI sector from a UK base.

Developments in telecoms AI can also lead to improvements in productivity for UK companies, with the benefits to the economy coming in the form of increased profitability, and hence corporate taxes, and improved competitiveness in the international marketplace. For example, delivery times and costs can be reduced by using AI to find efficiencies and savings in fleet management, by using mobile Telco data to avoid congested areas and times of day.

(81) UK ONS, Trade in Services (TS): Telecoms, Computer and Information Services: WW: Exports: BOP: CP: SA: £m

3.1.2/ Using AI and Telco data for Economic Analysis

Telcos produce a wealth of internet usage and footfall data which could be used for economic analysis and modelling.

Consumer behaviour is the most accurate assessor of consumer confidence, which in turn can not only reflect the economic reality, but also predict imminent changes in behaviour which may have profound economic implications, either positive or negative. For example, the number of new premium mobile handsets appearing in the market is a good indicator of consumer confidence, as phone upgrades are luxuries in tough economic times. Footfall data can also show changing patterns in where people shop for groceries and essentials, whether there's a trend towards premium or budget stores. Shopping patterns for non-essential or luxury items can also be gleaned from both footfall and internet traffic data.

Potentially anonymising Telco data and using it to train AI models to predict changes in consumer behaviour can allow government and businesses to see the tremors of emerging trends at the earliest stages, affording them time to mitigate risks if the trends are downwards, or maximise opportunities in times of growth. This AI modelling could be further enhanced by linking footfall data to underlying infrastructure, such as car parking, public transport, retail outlets, etc., and then using infrastructure data in areas where no footfall data is available, to predict economic patterns.

At a macroeconomic level, historical Telco and economic data going back decades could be used to hone the AI models trained to use such data as economic predictors, leveraging evolutionary big data and AI tools and solutions as they emerge in the market.

3.1.3/ Improving Public Service Delivery

The government spends over £1,000 billion annually delivering public services and AI in Telco can play a part in improving efficiency and efficacy of the delivery of services.

Mobile devices are part of everyday life for most people and more and more services are moving online for convenience. However, there are still many areas with high footfall and traffic where mobile performance is poor for individual MNOs, with insufficient mobile coverage or capacity to use online services. AI tools can be developed to help local authorities to factor in mobile coverage and performance when planning new infrastructure or services for the public, whether provided by the public or private sector. Below we give example use cases on public services where service spots can benefit from having the insights of mobile coverage leveraging AI tools.

Migration from cash to online payments - paid public parking is a perfect example where good mobile coverage is essential for all MNOs in a car park, before replacement of cash payment machines with an online app or service can be considered.

New services that require online access - rental of e-bikes, e- scooters, and ride-share vehicles require activation via a mobile app, so mobile coverage is important when considering new parking bays for rentals.

Public services where people wait for extended periods - there are many examples of services used by the public where people must wait for extended periods of time. While mobile coverage is not essential for these services, the public are more likely to use services where they can pass the time using their mobile devices while they wait. Examples of such services include EV charge points, playgrounds, healthcare facilities, educational facilities, and any public service delivered where a waiting room is part of the service delivery process.

3.1.4/ Harnessing the Creativity of SMEs

Opportunities exist for the UK government to help harness the creativity of SME and facilitate Telco AI new entrants in the UK.

The proliferation of IoT sensors in urban areas presents a great opportunity for SMEs to create innovative solutions that leverage sensor data. AI-driven advertising could factor in footfall and weather conditions. As conditions change, advertising could deliver special offers via digital window displays in the storefront to attract passers-by. For example, a window display in a coffee shop that says "step in out of the rain and enjoy a coffee for just £3 (normally £3.50)" would only be displayed when a nearby IoT weather sensor detects rain.

Mobile VR/AR apps need high bandwidth to operate effectively. As mobile data speeds improve with the rollout of 5G, 6G and beyond, creating new VR/AR mobile apps will become more attractive as the market develops. Opportunities exist not only in app development, but also in the development of new AR/VR headsets which use mobile data.

The UK Government has a track record of investing in innovation, and part of their strategy is to target funding at specific industries. For example, in September 2023, Innovate UK launched a fund called "Collaborative AI Solutions to improve productivity in key sectors", targeting the priority sectors of transport, construction, agriculture and creative industries.

An opportunity now exists for the UK government to launch a fund exclusively for SMEs to create innovative AI solutions in the Telco sector. Business models that are more in favour of innovation, e.g. opensource, can be leveraged. Such models provide SMEs access to enterprise technology without having compute infrastructure and specific expertise. SMEs have small development teams, and an agile development ethos is essential to their success. AI is evolving rapidly and providing funding for SMEs will allow them to focus their efforts on AI innovations in the Telco industry, which will undoubtedly lead to a wide range of solutions that will help position the UK as a world leader in Telco innovations.

3.1.5/ Turning R&D into Commercial Success

If the government is to invest in research in the Telco AI sector to boost the economy, its initiatives must not focus solely on what's possible, but also on what's internationally scalable.

There is no doubt that AI in Telco will develop rapidly over the coming years, and the government is expected to invest in research in the sector in order to put the UK at a leading position in this area. Many unicorns (companies with over $1 billion market valuation) are spawned from university research projects, and it is important for the government to ensure that there is funding and support for such projects, and a clear path from research projects to viable, scalable solutions and innovations with international appeal. The Telco equivalent of ChatGPT could be developed in the UK and rolled out worldwide in months, but the more funding the government provides for research in this area, the more likely this is to happen.

However, funding research alone will not guarantee success. An agile development ethos is a key ingredient in developing AI solutions, but it is equally important in turning research into commercially viable and scalable solutions. A government-funded task force of industry professionals with a proven track record of scaling tech products and solutions worldwide would be worth considering, to work in parallel with researchers. Developing Minimum Viable Products (MVPs) at the earliest possible stages in research projects will allow experts to evaluate the scalability of solutions, thereby mitigating against expensive market failures.

Funding to bring products to market quickly is also vital. Too often, companies, particularly SMEs, exhaust their finances in the R&D phase and don't have adequate resources to commercially exploit their innovations. The government, for its part, has a tendency to fund projects in the R&D phase but leave companies to fend for themselves when it comes to scaling and marketing new solutions. A change in approach by the government to include funding for companies as they move their products from development to production would allow them to scale rapidly and maximise the benefits to the economy at the earliest opportunity.

In assessing applications for funding and support for research in Telco AI, the Total Addressable Market (TAM) in target territories must be considered, as well as the viability of product rollouts in multiple new international markets simultaneously. The legislative frameworks in target markets, either existing or proposed, must also be factored in to ensure regulatory compliance. AI is evolving rapidly and governments around the world are working on introducing legislation to protect their citizens from any adverse effects of AI, whether unintentional or malicious. Scaling businesses internationally is generally not the forte of researchers, nor should it be, and it therefore makes sense to provide support for both research and business development in a two-pronged approach.

Sharing research knowledge is an important element of an open innovation ecosystem, but it is important to assure innovators that their intellectual property will be protected through appropriate licensing, whilst allowing their innovations to be used by others to develop new products and solutions that will benefit the economy. If government funding schemes aim to develop open systems and open data solutions, they must ensure that the companies and organisations which develop such systems are adequately compensated. The Public Sector Geospatial Agreement(82) is a great example of how this can work effectively, delivering open data from Ordnance Survey's OS Data Hub to the public sector, funded by central government and free to use by the public sector.

(82) OS, The Public Sector Geospatial Agreement

3.1.6/ The threat of Falling Behind Others

The UK faces stiff international competition in the race to develop innovative AI solutions in the Telco sector and a failure by the government to invest in the sector may lead to a migration of innovators to better-funded territories.

A recent analysis by Sifted(83) indicated a significant investment slowdown in 2023 in the UK, with founders of grow-stage companies arguing that the UK is not always favourable to ambitious founders. The UK government should do much more to support innovation, including in the field of Telco AI. Schemes such as the Innovate UK Smart Grants that seek to support ambitious, disruptive research and development (R&D) projects with a high commercial potential(84) fund less than 3.5% of the applications submitted and the average grant fund value per project is below £350K(85). The number of applications in the digital industries area is there, yet only 2% of them are funded. Similarly, the £100M funding package for Foundation Model Taskforce announced in 2023(86) faced criticism from founders who recognise that much more significant support is available in other countries. For instance, the EU recently passed a £43B incentive plan to support semiconductor manufacturing. While the UK maintained leadership in a number of sectors up until recently, including in semiconductors, companies in this space are now contemplating moving elsewhere, claiming a lack of UK government support as the main reason.

With telecom AI being in its infancy, the UK government has a unique opportunity to boost the development of innovative business in this space to gain a leading edge on the global stage.

Another important aspect to consider is the small number of university spinouts, which account for only 3% of the high growth companies in the UK. This is largely a consequence of the high equity stake universities take in such ventures, while putting founders at a disadvantage, as well as the absence of scale up capital(87). UK Universities have world-leading research output, but the current climate provides limited incentives for researchers to take their ideas out of the lab and into the creation of businesses. The UK Government is in a good position to influence a change in current university policies that stifle commercialisation of research and through this unlock the UK's potential to become a Telco AI super-power. The Chancellor's Autumn Statement 2023(88) makes good progress in this direction, recommending 10-25% university equity for life sciences spinouts, and 10% or less for less IP-intensive sectors, common in software. More sustained action in this direction would be welcome.

(83) UK investment falls off a cliff as government drags its heels on support, Kai Nicol-Schwarz
(84) UKRI Smart: innovation funding guidance
(85) UKRI - FOI2023/00609: Smart Grants: January 2023
(86) Initial £100 million for expert taskforce to help UK build and adopt next generation of safe AI, Government Press Release
(87) The growing tensions around spinouts at British universities FT Article
(88) The Chancellor's 2023 Autumn Statement

3.2/ Sustainability

In 2022, the GSMA's "Mobile Net Zero" report(89) revealed a significant increase in commitments to reduce carbon emissions among global operators. Specifically, 50 operators have pledged to decrease their carbon footprint over the next decade, marking a notable surge from the 19 pledges recorded in 2021. Moreover, operators constituting 44% of global telecom revenue, has made resolute commitments to achieving net-zero targets by the year 2050(90).

3.2.1/ Telco sustainability with AI

Opportunities continue to rise on the use of AI to provide a more efficient network by optimising their resource usage. In turn that means a network must be more flexible and adaptive to changing load and conditions.

According to research, 85% of energy consumed by Telcos is wasted due to inefficiencies, with approximately 85% of energy consumed deemed inefficient, primarily due to idle equipment. Although 5G networks are more energy-efficient per packet of data, the exponential increase in data usage is expected to drive power requirements up by a staggering 160% by 2030(91).

AI is expected to identify and reduce energy usage in the network by intelligently turning off equipment during periods of low demand, such as night-time. Moreover, AI-driven data centre cooling techniques have shown remarkable promise in optimising energy usage(92). Smarter mobile networks can reduce energy consumption by 30% to 40% in the long term.

(89) Mobile Net Zero – State of the Industry on Climate Action, GSMA, 2022
(90) 5 sustainability initiatives in the telecommunications industry | TechTarget
(91) The Economist, Data point: how 5G is an opportunity to tackle sustainability in telecommunications
(92) AI for data center cooling: More than a pipe dream - DCD (datacenterdynamics.com)

3.2.2/ Cost and Environmental Impact of AI

The disparity between the cost of AI training and the time required for a return on this investment, which may span several years, underscores the substantial challenges posed by the upfront investments required for Telco AI development in the UK.

While AI has demonstrated the advantages of reducing energy and network OPEX, the cost and environmental impact of AI should not be underestimated.

According to a MIT Technology review article(93), training a single AI model can emit as much carbon as five cars throughout their entire lifetime. On a similar note, training the most advanced Chat GPT 4 model consumes 50-60 GWh (Ref: Google), while it has been noted by an operator that the annual saving of network energy due to the use of automation and intelligence is 63.2 GWh.

The costs associated with training comprehensive AI models have been escalating significantly. Take, for instance, the ChatGPT 4 model, with training costs of $60 million over a span of just three months(94).

It is noted that not every telecommunications challenge necessitates the deployment of expensive generative AI models with billions of neurons; more cost-effective alternatives, such as reinforcement learning, often suffice. Nevertheless, it is essential for Telco industry and stakeholders to balance the financial considerations and environmental awareness when AI application to Telco is becoming widespread, especially taking into account of the sustainability goals specified in ITU-R framework for IMT-2030(95). The UK Wireless Infrastructure Strategy(96) is looking to shape development of 6G in a way that meets the UK's economic and societal needs.

(93) MIT Technology Review - Training a single AI model can emit as much carbon as five cars in their lifetimes
(94) GPT-4 architecture, datasets, costs and more leaked (the-decoder.com)
(95) IMT-2030
(96) Wireless Infrastructure Strategy - Chapter 5: Realising the full benefits of 5G and advanced wireless connectivity

3.2.3/ Supply Chain

Telecommunications is a key part of the UK's Critical National Infrastructure (CNI) (97), and as such the resilience of the supply chain is of great importance. Over the last 20 years there has been a great deal of consolidation in the vendor market, which combined with the Government's mandate to remove High Risk Vendors from the UK cellular networks leaves a very limited vendor ecosystem.

The findings of the Telecoms Diversification Taskforce, published in April 2021(98), highlight two priority areas for development where the UK has good capability (Para 63). The second of these is network O&M "Apps", an area that sees a high potential for AI to play a key role. The UK's combined academic strengths in networking and in AI mean that this is an area of high potential to introduce UK players to the supply chain. The increasing softwarisation and disaggregation of networks will lower the bar to entry, as potential new vendors will not need to offer a full network solution but can provide parts of the value chain such as these Apps.

3.3/ Skill Gap

3.3.1/ Upskill and Reskill the Workforces

The UK has a considerable advantage with a robust AI workforce as a thriving hub for AI innovation and talent acquisition. However, there's an imperative need to bridge skill gaps between AI and telecommunications.

Risk lies in Telco's challenge of both attracting and retaining AI-skilled professionals. Enhancing retention rates requires both investing in staff training and fostering a cultural shift within the Telco sector.

The rise of AI is dramatically redefining the job landscape. According to the World Economic Forum's Future of Jobs Report 2023, an estimated 23% of global jobs will undergo transformation in the next five years due to industry shifts, including those driven by artificial intelligence, text, image, and voice processing technologies(99).

(97) Critical National Infrastructure (CNI) Definition
(98) Telecoms Diversification Taskforce Findings and Report
(99) World Economic Forum, The Future of Jobs Report 2023

As AI technologies continue to advance and seamlessly integrate into network automation, roles that were historically manual are undergoing augmentation or full automation, enabling employees to shift their focus toward higher-level, strategic tasks. This transformative shift in workforce dynamics anticipates a reduced demand for positions traditionally held by telecom professionals, such as network technicians and customer service representatives. An illustrative example comes from Philip Jansen, the Chief Executive of BT, who suggests that the incorporation of AI across its operations could potentially lead to the elimination of approximately 10,000 positions(100).

In contrast, there is a growing need for experts in AI, data science, and other advanced technologies. The UK has a considerable advantage with a robust AI and software workforce. Multinational companies have exhibited a preference for hiring in the UK, exemplified by industry leaders Apple making recent high-profile hires in the country, in contrast to redundancies seen across the tech sector (101). This trend underscores the UK's appeal as a thriving hub for AI innovation and talent acquisition.

The transformation in workforce demands has resulted in a skills gap within the industry, with a significant number of existing telecom professionals lacking the essential competencies for working with AI and other cutting-edge technologies.

Telecoms organisations need to invest in upskilling their teams from core telecom capabilities to capabilities in cloud, automation, and AI.

Telco companies are actively seeking to infuse fresh talent from the thriving AI field into their ranks, recognising the value of AI expertise in their evolving landscape. However, implementing upskilling and reskilling programs can be costly and time-consuming. Telco companies are facing the challenges to compete with the competitive salaries offered in the AI sector, where demand for skilled professionals is high. In addition, many AI engineers, despite their technical proficiency, find it challenging to fit in the Telco environment if they lack specialised telecom knowledge and a conducive culture that fosters their growth and integration.

(100) Guardian Article, BT to axe up to 55,000 jobs by 2030 as it pushes into AI, Mark Sweney
(101) Apple to buck layoff trend by hiring UK AI staff - BBC News

We note that retaining the fresh talent in the Telco sector not only requires training of AI and data engineers with relevant Telco expertise but also fostering a cultural transformation within the industry, including fostering a culture of innovation and digital career paths. For example, according to a TM Forum survey in 2022, British respondents consider the telecoms industry to be a software-focused and customer-facing with work that includes "cable laying" and "call centres", and the industry is perceived to have an outdated work culture where jobs are not 'exciting' or 'innovative'(102).

3.3.2/ Higher Education and Training

Opportunities exist for the UK to develop new university degrees that cross the boundaries between AI and telecommunications to give the UK a competitive advantage for skills needed to boost the development of future communication networks.

UK Universities such as Cambridge, Oxford, Imperial, Edinburgh, UCL, KCL and others, offer both undergraduate and taught postgraduate degrees in AI, which constitute an important skills pipeline which various industries can tap into. The UK Research and Innovation council also funds several Centres for Doctoral Training that seek to produce the future generation of research leaders in the field of AI. Developing AI solutions for the Telecommunications sector, however, requires deep sector knowledge upon which existing AI degree programs touch only superficially through general course modules on computer and communication networks, extreme computing, or IoT systems.

Likewise, electrical/computer engineering degrees that train future networking/telecommunications practitioners, while they frequently give students grounding in topics such as linear algebra and discrete mathematics, which are foundations to AI, they rarely go beyond covering applied data science concepts. They neither cover ancillary topics relevant to building AI solutions, including distributed file systems, database systems, data engineering, and cloud computing.

This skills gap is not only seen in the UK, but in general throughout higher education worldwide, as computer science and engineering disciplines have historically been somewhat disconnected.

(102) EnergyREV.org, How to attract digital talent to the telecommunications industry

Other countries are beginning to focus on AI skills creation for the telecom industry. As an example, reports mention how India's telecoms companies(103) have had a significant increase in AI skills. Nasscom, India's IT trade organisation also reports(104) that India leads the G20 and OECD countries in terms of AI skills.

3.3.3/ Foster Innovation through Pilot Initiatives

Opportunities are emerging to cultivate the UK's Telco AI ecosystem by fostering collaborative pilot projects and extending support for AI initiatives within the telecommunications sector. Commercial viability of the results generated from these initiatives must be carefully considered.

The complex dynamics in Telco AI, coupled with its extensive interplay with other facets of telecom, demand seamless integration and holistic advancement along the value chain rather than fragmented development. This underscores the paramount need for collaboration where stakeholders can harness collective expertise, tackle industry-wide challenges, and co-create solutions that are both comprehensive and scalable.

Collaborative pilot initiatives can significantly foster innovation and incubating startups within the dynamic landscape of AI in the UK telecommunications sector. These initiatives are instrumental in the "learning by doing" approach, allowing industry players, startups, and researchers to gain invaluable training of necessary expertise, supporting the growth and development of innovative startups in the UK, and helping grow the UK's Telco AI ecosystem.

Pilot initiatives serve as powerful catalysts for the accelerated adoption of AI in the telecommunications sector, fostering innovation, and testing the waters for ground breaking solutions and transformation. To stimulate and sustain these initiatives effectively, it's crucial to provide comprehensive support for the essential resources required, for example, provisioning computing resources, and facilitating the projects. Currently, such AI accelerator programs are in place for various sectors, including agriculture, creative industries, construction, and transportation(105). Expanding these initiatives to include the telecommunications sector, especially when commercial viability of the results generated from these initiatives are carefully considered, can greatly enhance AI integration, encourage experimentation, and ultimately drive advancements both in the industry and in the UK Telco AI ecosystem.

(103) ET Telecoms.com, Total share of AI/ML workforce in telcos at 20% in just a year
(104) ET Telecoms.com, India top country in AI skill penetration globally: Nasscom
(105) Digital Catapult BridgeAI Programme

3.4/ Ethics and Regulations

3.4.1/ Introduction

We are very aware that ethics and regulation constrain and influence how organisations – through the actions of their people and systems – operate and behave, by setting out frameworks of rules, guidelines, and boundaries, that describe what is and is not acceptable.
The scope of this influence and constraint on Telco AI is two-fold: application and use of AI throughout a telecom's organisation in its day-to-day operation; and the development and management of AI for such uses.
There are two overlapping areas of Telco AI influence:

- Relevant ethics and regulations for all sectors e.g. anti-discrimination laws, GDPR; and
- Relevant ethics and regulations specific to telecoms e.g. universal service obligations, proposed telecoms security regulations, etc.

Ethics vs Regulation
The distinction between ethics and regulation arises because the clarity, applicability and enforcement of the issues involved vary widely.

"Regulation" refers to externally defined rules of how business should and should not be done, with prescribed boundaries of what is and is not acceptable. These are articulated through laws set by governments, and regulations set by regulators such as Ofcom.

In contrast, "ethics" is a less clear term, generally understood to mean some form of "doing the right thing". But of course, "right" depends on context, circumstances, and speaker, and varies significantly across societies, organisations, and individuals.

In many cases, regulations exist for ethical reasons such as protecting consumers and employees or preventing financial misconduct. This means many ethical requirements are implicit in regulation, leaving ethical discussions in business for "greyer" areas, where obligations are less stringent and/or more open to debate, for example whether to offer facial recognition solutions to law enforcement customers. Ethical issues can also be precursors to future regulation, perhaps in response to subsequent public response, legal debate, or unforeseen consequences.

In practice, "ethics" refers to business policies, working practices, organisational norms (e.g. codes of conduct) and so on, that go beyond regulatory (including legal) obligations.

Ethics and Regulation in Telco AI

The discussion of ethics and regulation in this paper covers the areas where AI adds new ethical and regulatory considerations for telecoms or adds complexity to current ethical and regulatory areas for telecoms.

For ethics, this consists of 6 aspects of AI ethics for Telcos, grouped into three related pairs:

- Fairness & Privacy;
- Explainability & Autonomy;
- Accountability & Safety.

Each of these is a complex topic in its own right, and the implications for Telcos cannot be explored in depth in this paper. Instead, each is introduced briefly, and the aspects which should be considered by Telcos as part of their adoption of AI are described.

For regulation, this section signposts the 6 most important laws, regulations or institutions that could affect AI in Telcos. Again, it is not possible or appropriate to discuss each of these in detail here.

3.4.2/ AI Ethics

AI researchers and practitioners have proposed many conceptual models to frame AI ethics work. In this paper, we have consolidated the most common themes [refs – see 0] across these into six categories of AI ethics consideration and applied them to telecoms. These are: Fairness; Privacy; Explainability; Autonomy; Accountability; Safety.

3.4.2.1/ Fairness and Privacy

“Fairness” is a concept typically associated with ethical behaviour, both broadly in society and more specifically in business. However, it is not an unambiguous or clearly defined term, especially across research disciplines, and often used synonymously with words like “justice”, “equity”, “equality” and “impartiality”.

In business, the focus is generally on one specific form of fairness: avoiding biased behaviour which discriminates against people – individuals or groups – on the basis of their defined characteristics. In UK law, these are known as the nine “protected characteristics”, and include sexual orientation, religion, disability, etc.

Privacy is universally acknowledged as a fundamental human right and safeguarded by numerous legislative measures. It is closely linked to fairness, because not only must personal data not be used in a discriminatory way, it must also be kept private. In practice, this means AI systems must use personal data in a way that complies with laws such as the UK's Data Protection Act and EU's GDPR, depending on jurisdiction.

However, it is well publicised that AI has in the past led to unfairness in business, for example in recruitment, reinforcing historical gender bias. There are also many reports of discriminatory AI technology, for example racism in facial recognition algorithms. In such cases, not only are there ethics questions around fairness, but also whether AI is using personal data appropriately.

Such ethical problems can arise in any sector, including telecoms. However, Telcos face a specific issue because network data – at the heart of Telco AI – is rich with personal data, from caller identity to device details and location. The power of AI arises in part because of its ability to bring together data from disparate sources and draw inferences from patterns that may not be apparent from the individual datasets. In telecoms, AI fairness and privacy risks arise when network data is merged with other data and creates patterns that may be unethical, even if inadvertent.

Solutions to detect, correct and prevent such issues in AI already exist, and more sophisticated, reliable solutions are being developed across the global AI industry. Many of these involve technical activities during AI development, for example ensuring AI training data is representative or detecting inappropriate bias in algorithm design. AI fairness is also addressed beyond the technology, for example in product/service design, business processes, and human intervention.

This has led to a wide range of AI fairness and privacy tools and services, suitable for technical and business audiences. For example, fairness tool sets can be used to inspect code and data, while AI ethics audits can identify risks in business logic and product design.

Telcos need to adopt such mechanisms in two ways. Firstly, AI development practices should incorporate best practice mechanisms from across sectors, not just telecoms, because of the relative lack of Telco AI maturity. Secondly, Telcos should develop industry-specific fairness and privacy solutions for AI activities such as network testing.

As well as such mechanisms, another approach to addressing ethical issues around AI fairness and privacy involves the next two AI ethics themes: explainability and autonomy.

3.4.2.2/ Explainability and Autonomy

Explainability – often discussed hand-in-hand with transparency – is the ability to retrospectively understand how a decision was reached by an AI system. Transparency refers to the feature of AI systems that allows the flow of data and logic to be unambiguously traced, from input to decision. While transparency tends to involve technical detail, explainability information should be accessible to business users and others that don't necessarily have technical skills.

The reason these can become issues is that AI algorithms typically evaluate many (thousands, millions or more) different ways of processing data to reach an optimal decision, and the most technically efficient way of doing this generally involves presenting AI as a black box, only reporting the final result. A further complication is that AI will evolve over time, potentially using different versions of an algorithm at different times.

Modern AI development techniques can now address this in various ways, with the most advanced approaches coming from industries where AI transparency is mission-critical. However, this is not the case in Telco AI, and transparency is not necessarily a priority for AI work in many Telcos.

Closely related to explainability is the concept of autonomy, which refers to whether an AI system is permitted to make decisions entirely by itself, or whether humans are involved. The involvement may be part of the decision-making process or could be oversight of the AI decisions.

In Telco AI, autonomy is a potential issue in network management and AI-native architectures in particular, for example the desire to use AI to create self-healing and knowledge-defined networks. Other areas heavily impacted by these ethical issues are more similar to other industries and can be addressed by looking outside the telecoms sector, for example ensuring OSS explainability.

These and similar AI uses are part of the overall discussion Telcos need to address in their AI strategies: how much automation and autonomy are they aiming to achieve through AI use, especially around the network. The more ambitious their goals, the fewer people will be involved in what were previously highly people-intensive activities.

3.4.2.3/ Accountability & Safety

Ultimately, when things go wrong, organisations need to be accountable. The consequences on those who are accountable increase in severity when the errors lead to harm.

However, accountability is generally set through existing governance and legal frameworks, which were designed in times before AI was prevalent. Today, there is an ongoing debate about whether AI requires its own governance and accountability, or whether it needs to be incorporated into existing structures.

AI audit is a growing field, linked to the idea of requiring organisations to certify that their AI systems meet ethical or legal standards. There are not as yet any agreed rules for such standards, but several have been proposed. Governments are consulting with stakeholders on such standards as part of upcoming AI legislation, and various Ethical AI institutions are proposing independent frameworks, often aiming to exceed likely legal standards.

All such proposals have two things in common. Firstly, they require an assessment of the degree of potential harm arising from errors in an AI system and provide different degrees of rigour for different degrees of potential harm. Secondly, they require explicit governance structures to be in place which are accountable for the consequences of any harm arising from AI mishaps.

The telecoms industry does not directly fall into a category where safety is critical, compared to say airlines or power generation. However, telecoms networks do form a nation's critical infrastructure, so potential AI failure should be treated as a very high priority by Telcos.

3.4.3/ AI Regulation

The laws and regulations applicable to AI use in Telecoms businesses fall into three groups:

- General business laws and regulations covering all sectors e.g. employment, anti-discrimination, data privacy, digital business.
- Telecoms-specific laws and regulation, such as the Communications Act and Wireless Telegraphy Act of 2003 and 2006 respectively.
- AI-specific laws and regulation.

There is a particular complexity around the third of these, AI-specific laws, because these are still in the process of being set, and there are differing approaches across national jurisdictions. An important, distinctive feature of the UK approach to AI regulation is a broadly sectoral approach, with no single overarching AI regulator.

UK Telcos will need to determine which AI rules apply to them and which regulatory and legal authorities are responsible for these. This will depend on individual circumstances, for example their countries of origin, ownership and operation, and the nature of activities using AI.

One significant implication of the current status of AI regulation is that telecoms AI activities and plans will need to take account of potential regulatory and legal compliance requirements which are a) not yet finalised and b) may well evolve as the wider implications of AI become better understood by lawmakers and regulators.

There are six current and likely future laws and regulations most relevant for current and future AI work in telecoms:

- UK Government AI White Paper(106);
- EU AI Act(107);
- ICO (Information Commissioner's Office) Guidance on AI & Data Protection(108);
- CMA (Competition & Markets Authority) AI Foundation Models review(109);
- Ofcom consultations and reviews, initially focused on generative AI(110);
- Online Safety Bill/Online Harms White Paper(111).

(106) A pro-innovation approach to AI regulation policy paper
(107) European Parliament, EU AI Act: first regulation on artificial intelligence
(108) Guidance on AI and data protection
(109) AI Foundation Models: Initial report
(110) Ofcom Article, Gen Z driving early adoption of Gen AI, our latest research shows
(111) Online Harms White Paper

3.5/ AI Security

The multifaceted evolution of AI systems brings forth significant security implications. Whilst AI security is a multi-industry adoption challenge, telecommunications is a Critical Infrastructure Provider for which there are additional significant regulatory requirements especially on the Operational Technology that provides the communications services (as distinct from supporting IT).

The growth of cybersecurity threats and their impact on critical infrastructure providers is a concern to governments and societies across the globe that has resulted in actions by governments with support from their national cyber security agencies.

The following sections describe: the main UK actions affecting Telecom AI Security, the challenges of increased threat surfaces arising from use of AI, Supply Chain Security for AI (both with examples originating from the UKTIN AI Security Group discussions); And a comparison with Global actions on Telecom AI. The group recommends interested readers to find more details in the UKTIN Security EWG paper.

These challenges arise from increased complexity of operating AI solutions for telecom, making it difficult for Telcos to effectively own/operate their own networks themselves (as required by Telcom Security Act in UK).

3.5.1/ AI Expands Telecom Cybersecurity Threat Surface

Use of AI within networks expands the traditional network threat surface:

from	hardware based network devices where the principal threat surface is interfaces and protocols.
to	AI and software-based network solutions which add threats through APIs, software update tools, and processes including supply chain process, management processes, model data, AI training, and operational people skills.

Examples of increased threat surfaces include:

- Telecoms vendors seek remote access to the systems they install in operator environments, to provide technical support, and provide managed services such as upgrades and maintenance. AI systems provide a new risk channel, in that the loading of a model is likely to present a difficult-to-manage risk – pre-trained models are opaque "blobs" of data, and it is not feasible to compare or inspect these and understand the changes made.
- In use of AI in classifying and categorising traffic flows for security-related indications. An AI classifier could be trained on both malicious and benign traffic, and then attempt to detect new, previously unseen, traffic flows or patterns. A clear opportunity exists here for an adversary to (for example) use their own training datasets which are derived from legitimate data, but which also contain data approximating some of their own "prepared" weaponised attack techniques, in order to train the classifier not to alert on such traffic.

3.5.2/ Supply Chain Security for AI

Telecom AI Solutions and their deployment is increasing the number of suppliers and the complexity of their relationship both for AI (Inference) engines and the provenance of pre-trained models, and training processes for self-trained models.

Governance concerns are leading to proposal for:

- Software Bill of Material (SBOM) that can be applied to AI software training and training data(112), see Software Bill of Materials (SBOM) | CISA] that can be applied to AI software training and training data
- Hardware Bill of Material (HBOM) for telecom supply chains, that can be applied to AI semiconductor developments. See Hardware Bill of Materials (HBOM) Framework for Supply Chain Risk Management | CISA(113).

(112) America's Cyber Defence Agency, Software Bill of Materials (SBOM)
(113) America's Cyber Defence Agency, Hardware Bill of Materials (HBOM) Framework for Supply Chain Risk Management

Examples of Supply Chain Challenges for Telecom AI Security:

- The costs of hardware required for efficient model training (like leading-edge AI series GPUs is leading to a shift towards use of multi-tenant cloud-based computing. Where servers or GPUs are outside of the control of the telecoms company there is the potential for residual code to "inject" into training processes and it is very hard (or impossible) to inspect an AI model (i.e. the output of a training process) and tell whether it is legitimate, correct, or tampered with.
- ECSMR Section 7(5) also sets out an obligation on operators to have at all times a written plan to "maintain the normal operation of the public electronic communications network in the event that... a third-party supplier is interrupted".

3.5.3/ Security Impacts on Telecom AI

Securing Telcom Use of AI to meet UK Cybersecurity and Telecom security code of practice for Network Resilience (see Annex E) requires new tools for AI security management. These requirements create opportunities for AI investment including:

- Tools for managing supply chain integrity of AI application, algorithms, and training data between suppliers and telecom providers.
- Tools for managing technical development, deployment and operation of AI technologies, e.g. neural network inference engines, and operational data feeds that fine tune and continuously adjust training parameters.
- Tools for Governing AI implementation and deployment
- Consulting and training services for establishing AI Cyber security regimes in the Telecom Supply Chain, training Cyber Security personnel and auditing.
- Extended Detection and Response (XDR) Applications utilising AI for monitoring of running applications that detect and remediate cybersecurity threats and compromises.

3.5.4/ Global actions Telecom AI Security

UK actions are mirrored by similar initiatives in the US, Canada, Australia, New Zealand, Europe, and others. These initiatives are creating similar demands on telecom providers globally to those in the UK but slightly behind the UK form a regulatory viewpoint. A list of UK Actions impacting Telecom AI Security has been summarised in Annex G.

Relevant announcements include:

- White House March 2023 National-Cybersecurity-Strategy-2023.pdf (whitehouse.gov)
- CSI_EMBRACING_ZT_SECURITY_MODEL_UOO115131-21.PDF (defense.gov)
- Implementing a Zero Trust Architecture NIST SP 1800-35 Practice Guide Third Preliminary Draft | NCCoE
- NIST AIRC – Home Trustworthy & Responsible AI Resource Centre
- AI RMF Development | NIST AI Risk Management Framework
- Software Bill of Materials sbom_minimum_elements_report.pdf (doc.gov)
- ETSI GR SAI 004 - V1.1.1 - Securing Artificial Intelligence (SAI); Problem Statement (etsi.org)
- 2023-2030 Australian Cyber Security Strategy (homeaffairs.gov.au)

These initiatives will also stimulate global demand for Telecom AI Security tools described earlier.

4/ Future Topics

In addition to further in-depth studies of the topics in this paper, the AI EWG has identified two subjects for in-depth study in the next publication of this paper. This section provides a brief overview of these two topics, while comprehensive studies delving into their impact on the telecommunications sector will be conducted in the next AI EWG paper.

4.1/ Generative AI

Generative AI surged onto the world stage with ChatGPT in 2022. IBM(114) has found that 97% of telecom providers have benefited from use of Conversational AI for customer service which sets the stage for evolution towards Generative AI in this area for aspects such as call summarisation, and multilingual customer service support. Telecoms organisations are now beginning to evaluate and trial Generative AI in other core telecoms areas such as AI/ML Ops, RAN Optimisation and others.

The latter half of 2023 has seen a remarkable surge of interest in the application of Generative AI within the Telco industry. Operators have reacted fast to embrace the new opportunities that can potentially be brought by Generative AI . Many believe that Generative AI will enable new capabilities in Telco and enable use cases that are not currently served by existing AI applications and processes (see Figure 4)(75).

According to an AWS survey (115), half of the Telcos stated their intentions to integrate generative AI within the next two years, marking an unprecedented pace of adoption within the Telco sector. In addition, SK Telecom's (SKT) has announced their integration of Gen AI into their network operations, exemplify this industry-wide shift.

(114) IBM, Elevating telecom customer service
(115) AWS from MWC: Half of telcos expect to adopt GenAI within two years, Kelly Hill, RCR Wireless

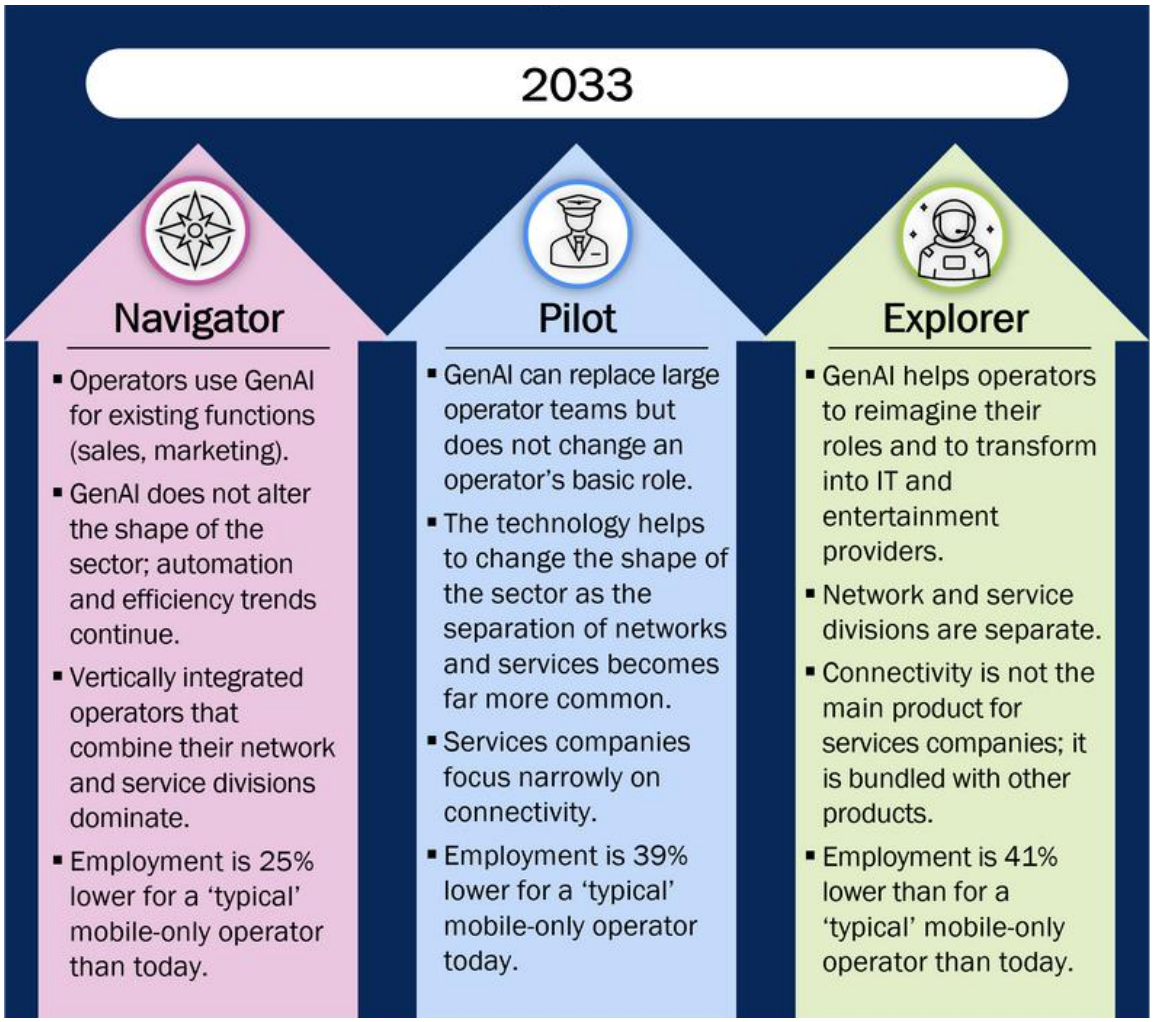

Figure 4 Potentials of GenAI on the Scenarios for GenAI and telecoms in 2033 [Analysys Mason]

This strategic move mirrors the broader trend within Communication Service Providers (CSPs) as they strive to transition from traditional Telco providers into technology companies (Techcos). While the full ramifications of Gen AI on Telco customer service and network operations are yet to fully unfold, it is evident that its potential should not be underestimated. Gen AI has the capacity to catalyse a profound transformation across Telco networks, business models, and the broader technological landscape, ushering in a new era of innovation and adaptability. As the telecom sector embraces Gen AI, its influence and reality on shaping the Telco industry should be closely monitored in the years ahead.

4.2/ Quantum Computing and AI

Quantum computing, unlike classical computing that uses bits (binary digits) to represent either 0 or 1, relies on qubits (quantum bits) which can represent either 0, 1, or both 0 and 1 simultaneously, thanks to the quantum phenomenon called superposition. This enables quantum computers to perform complex computations at a much faster rate than classical computers(116). The expectation is that the impact of quantum computing on AI will be in three key areas:

1. Enhanced Machine Learning Models: Quantum computing promises to supercharge the development of advanced machine learning models. Vodafone is exploring this specific area to help decide where to place antennas for optimal connectivity(117).
2. Accelerated Data Processing & Analysis: Quantum computing's immense processing capabilities can significantly expedite data analysis.
3. Heightened Security: Combining the power of quantum computing with AI capability for learning & predictions provides mechanisms to enhance threat detection and secure communication networks(118).

As Quantum AI continues to advance, it holds the potential to unlock new opportunities in Telco and meet the ever-growing computational demands to realise Telco AI. The EWG will continue to monitor these developments, and report how telecommunications companies harness this technology for innovation in the coming year.

(116) IBM, IBM AI and Data Science, Master the art of data science.
(117) Vodafone and IBM on Quantum Computing
(118) Quantum AI: The Future of Cybersecurity (kiteworks.com)

5/ Summary of Competitive Analysis of the UK

For each section in the Key Topics, we provided a view on the state of the art followed by its emerging technology trends. Here, we summarise the key strength of the AI technologies covered in this report followed by the opportunities it may offer to the telecom marketplace. A summary of the weaknesses and threats are also provided in this section.

5.1/ Strengths

The UK offers a breadth and depth of knowledge for AI in the Telco domain.

The UK is home to MNOs that have the potential to drive considerable investment and innovation within the UK. As an example, Vodafone commits considerable resources to open RAN technologies. It has also invested in a R&D lab for microchip architecture, albeit in Spain, to assess innovations and shape requirements in silicon infrastructure.

The UK has a breadth and depth of domain knowledge in telecoms and wireless technologies. It has a long history at the forefront of wireless technology, dating back to its invention by Marconi, through the development of the cellular industry. This has created a broad expertise across many elements of the telecom's ecosystem. Today, this exists as a constellation of many SME ranging from IP vendors, such as AccelerComm and Picocom, to engineering consultancies such as Cambridge Consultants, to larger IT consultancies like Accenture and EW, to telecom AI specialists such as NetAI, and the UK based MNOs BT and Vodafone. There are also development offices for non-UK companies such as hyper scalers, and some of the network equipment vendor.

There are many 5G test labs and test centres across the UK, which give a foundation to test and develop AI for telecoms at a small scale for early research and SME.

The UK is home to several specialist communications companies, who operate complete networks and design bespoke technologies to meet these challenges. They are world leaders in their specific domains. For instance, Ocado licences robotic warehousing systems which demands advanced wireless communications to control an extremely high density of moving robots. The technology is at the forefront of the Industrial IoT sector.

SUMMARY ANALYSIS

OneWeb is a leading satellite communications company, a sector set to grow rapidly in the next few years, with many new technical challenges ahead. AI will play an essential role in delivering the network, and leadership here could apply to many other satellite constellations.

Additionally, the UK has made substantial contributions to the field of AI, underscored by contributions from research institutes like Alan Turing Institute (119), other entities like DeepMind (120), and more recent announcement of £225m investment from the Government (121) to create the UK's fastest supercomputer at the University of Bristol the Isambard-AI, to become operational at the National Composites Centre (NCC) in the summer of 2024. There are also many 5G test labs and test centres across the UK, which give a foundation to test and develop AI for telecoms at a small scale for early research and SME.

The success of any AI system relies heavily on a profound understanding of its application, and the UK's strengths in telecoms and wireless networking provide a crucial foundation in this regard. The UK has a storied history in semiconductor and processor design, reflecting its deep expertise in creating the fundamental building blocks of modern computing. There is also a strong UK test and measurement industry presence, especially lab tests, field tests and assurance. These strengths, spanning from processor design to AI innovation and a deep knowledge of telecommunications from infrastructure, network design, to testing, position the UK well for R&D&I to realise technical innovations to achieve the convergence of connectivity and intelligence.

(119) The Alan Turing Institute
(120) Google Deepmind
(121) November: Unprecedented £225m investment to create UK's most powerful supercomputer | News and features | University of Bristol

5.2/ Opportunities

A fertile ground for new disruptive technologies

All through the paper, we have identified a number of Telco AI's research, development, innovation, and business opportunities across the industry. Here is a summary, we wanted to highlight that AI's rapid evolution offers a fertile ground for new disruptive technologies to take root. As telecoms develops from mobile broadband towards connectivity for everything, specialist communications in local niches become global standards with significant ecosystems. Building leadership in early-stage specialist communications, which includes the AI to automate and optimise the networks, creates the potential to lead the future global ecosystem in Telco AI.

6G is declared as AI native, which opens the door to massive innovation backed by the huge investment potential of the global 3GPP ecosystem. This presents an opportunity to move advanced academic research and early-stage innovative companies to commercial success and operations at significant success.

Harness opportunities for new market entrants

All through the paper, a number of opportunities have been identified for Telco AI new entrants with the changing ecosystem. Although the UK is strong in AI R&D in other sectors such as medical and finance, there is a lack of strong Telco AI presence at the moment, without UK owned network equipment vendor and hyperscalers. With the changing landscape of Telco AI, its ecosystems and network and business operations, opportunities exist in the UK to foster new market entrants, in areas such as system integrators, network orchestrators, and network data monetisation.

Potential to attract inward investment

The UK's commitment to innovation and proactive approach to nurturing collaborative partnerships through dedicated innovation funds, are establishing in the UK a thriving Telco AI ecosystem encouraging co-innovation and growth. UK has a successful track record in launching and having startups acquired, sets a compelling precedent for potential investors seeking a forward-thinking and dynamic environment. Opportunities also exist for the UK to attract R&D investment from major technology corporations around the world, where inward investment may be attracted by creating an environment that aligns with the evolving needs of investment seeking long-term, impactful engagements, such as technological

advancements, streamlined processes, sustainable practices, understanding of market dynamics, as well as diverse culture and languages.

Moreover, the UK's leading position in AI safety and regulation significantly heightens its potential to pioneer robust safety measures and regulatory frameworks places the UK at the forefront of cultivating an innovative environment conducive to AI growth. This not only assures businesses the reliability of the ecosystem but also underscores the commitment to advancing AI technology within a secure and compliant landscape, further enhancing the UK as an investment destination for those at the forefront of technological innovation.

5.3/ Gaps and Threats

While the UK has a respectable presence in various technology domains, there are notable gaps in its representation of next-generation telecom architectures. These advanced systems, which are pioneering AI and moving toward AI-native telecoms, currently lack a significant UK presence. A prime example of this discrepancy can be seen in the absence of RIC vendors or development centres within the UK.

In addition, the UK currently lacks substantial network equipment vendor development centres that specialise in AI, whereas major NEPs are at the forefront of AI in telecoms development. This discrepancy creates a notable gap in technical expertise and experience within the UK. These challenges underscore the importance of fostering a more robust UK presence in the development and implementation of AI within the telecom industry.

Furthermore, the retention of AI skills within the telecom sector proves to be a challenging task, as these coveted skills are in high demand across a multitude of industries, leading to a talent competition that threatens to draw these experts away.

While the UK has made significant investments in a world-class supercomputer housed at the Edinburgh Parallel Computing Centre, it is considered inadequate, primarily because of the rapid advancements in GPU chip technology. The telecoms industry may be transformed by the engagement of hyper scalers, as they have transformed other industries. This could result in the centralisation of development within the hyper scalers, which may be located outside the UK. In addition, existing powerhouse semiconductor players are also majorly located in the US, which poses potential security and privacy issues.

6/ Recommendations

The body of this paper contains numerous detailed insights and recommendations about the opportunities and challenges AI presents to Telcos. Many of these are directly relevant to individual organisations, informing their respective AI plans and activities.

This closing section offers a wide perspective in drawing together key themes from different sections of this paper into a set of recommendations as per terms of reference in drafting this paper.

This Expert Working Group is concluding their findings with a brief reminder of four insights drawn from the body of the paper, which set the context for recommendations and priorities for R&D and innovation opportunities through deployment of AI within the UK Telecoms solutions.

6.1/ Recommendation:1 – Future Network Platforms

Create a Future Network Platform and Innovation Program for co-innovation and experimentation of AI transformative capabilities in future Telco with stakeholders.

It is recommended from the group that an initiative of a Future Network Platform to nurture co-creation and experimentation through funded Proof of Concepts (PoCs) is highly desired. This initiative could fall under the umbrella of the Future Telecoms Institute (FTI), assuming its establishment, and focus on developing PoCs related to business transformation, technology, and service innovation e.g. evolution of the Digital Catapult approach. This approach ensures a stepwise progression from early-stage development to more advanced stages, with an emphasis on PoC viability.

It is becoming increasingly evident that technology convergence and cross-domain disciplines are pushing the boundaries of technology evolution. We are seeing more and more transformative use cases occurring at the intersection across technology disciplines, for example, between connectivity & intelligence, AI & cloud, AI & edge, edge & compute.

Telco network is a critical infrastructure that supports and impacts the research and innovation for a variety of sectors. New transformative services and business models are emerging. A number of examples in the paper have shown the shift of Telco strategy and the transformation of Telco to Techco.

To achieve this, 'blueprint' design to proof of concept, feasibility and potential benefits of business and service transformation opportunities is highly desired for third party buy-in, share lessons learnt, and upskill and reskill workforces.

It is envisaged that the Future Network Platform would serve the following purpose:

- Catalyse fast track innovations and disruption on AI capabilities in Telco technology, services, and business transformation.
- Develop PoCs that attract third-party buy-in, fostering collaboration and partnership with diverse stakeholders including new entrants and SMEs
- As a training platform to share lessons learnt and best practice, upskill and reskill workforces to meet the demands for future AI-powered Telco and cloud providers.
- Promote collaboration with international stakeholders to tap into global expertise, and attract investments on future Telco in the UK

UK Telcos are making great strides individually to develop AI capability and expertise, with one common motivation likely to be to gain competitive advantage over each other. The result is huge amounts of fragmented, duplicated effort, and a slow rate of advancement of AI maturity across the industry. Meanwhile, potential new entrants from the technology sector, primarily from outside the UK, already enjoy a substantial AI advantage which is likely to only increase. This points us to the direction of creating new technology, service, and business opportunities with collaboration among the wider stakeholders.

The traditional model of a prolonged investment and ROI cycle in the telecommunications industry is no longer suitable, especially in the face of rapid technological evolution driven by AI. To address this, the group recommends establishing a platform that significantly reduces barriers to innovation, leveraging shared data and network APIs to allow the co-innovation from other stakeholders, such as verticals, new entrants, and SMEs. This platform should facilitate the prompt development and testing of disruptive ideas and allow disruptive ideas to be promptly developed and tested, adhering to the principle in tech companies - 'innovate fast and fail fast'. Given the fast-growing opportunities in Telco AI, and the rapid pace of advancement of AI, there is only a narrow window of innovation before it is lost. It is recommended that the initiative be created as soon as possible, accompanied by funded innovation programs, serving as catalysts to foster innovation. This approach aims to establish the UK's distinctive edge for AI transformative capabilities for future telecommunications.

6.2/ Recommendation 2: Open6G Testbed

Establish a cohesive 'Open6G' testbed that facilitates the seamless integration and assessment of multivendor interoperability solutions for native AI network elements and testbeds.

This testbed will serve as a comprehensive platform for evaluating the compatibility and effectiveness of various AI-driven components from different vendors, ensuring a unified and efficient operational environment for the next generation of integrated communication, computing, and sensing networks.

In light of DSIT's strong emphasis on vendor diversity and the potential challenges posed by the advent of native AI and 6G, it is crucial to address multi vendor interoperability issues concerning AI network elements. The ongoing 3GPP work on AI/ML in the Air Interface and Core networks has focused on simpler AI elements at individual domains, yet the complexities arise as AI needs to be deployed cross-domain and end to end, and solutions to be provided by different vendors in different domains.

To effectively tackle these challenges, it is recommended to consider that the proposed activity aligns with the existing initiatives, such as SONIC Labs. Given SONIC's coverage of RIC and early AI integration into certain RAN aspects, an extension of its scope to encompass native AI in the broader context of 'Open6G' could be explored. This evolution to native AI within the RAN could naturally become a follow-on activity for SONIC once the equipment attains the required maturity and open interfaces.

This extension would involve assessing the compatibility of native AI elements and multi vendor interoperability solutions within the broader network context. As the Technology Readiness Level (TRL) increases and elements conform to standardised open interfaces, suitable PoCs from the Future Network Platform (Recommendation 1) could seamlessly transition to SONIC, ensuring a cohesive and comprehensive approach to the evolving landscape of AI in network elements. The overarching goal is to maintain a testbed that is able to accommodate the integration of diverse ‘AI-native’ network components from different vendors, along with technological advancements.

6.3/ Recommendation 3: Unified Data Access

Create unified Data Accessibility Initiatives towards the goal of safely opening network data and facilitating data sharing for the UK telecom ecosystem.

Data from telecoms networks have been identified as a key resource and the first hurdle for the development of AI innovations. While the UK is home to large telecom businesses, such data is kept closed as it may contain intelligence on their competitive advantage. As shown by a number of examples in this paper, great opportunities exist on creating unified data accessibility that would be the innovation catalyst, boost the Telco ecosystem and UK economy, provided there is a strong and secure data governance framework.

We note there are various methods available to generate secure and high quality dataset, including using synthetic data and advanced AI technologies for data generation with a much smaller dataset.

It is recommended that an initiative (e.g., Gaia-X data space and alike) be created to facilitate safe and secure sharing or generating of Telco data sets for both Telco AI R&D&I in the UK, as well as catalysing the thriving ecosystem leveraging Telco data. The initiative may include, for example, Policy and Governance, Stakeholders including Telco verticals, and Infrastructure.

6.4/ Recommendation 4: Telco-AI Initiatives

Form a mechanism to encourage and incubate radical, creative, fresh thinking research translation and adoption from SME and Universities on Telco AI business growth ideas.

The UK has a rich heritage of technology innovation and pioneering R&D, albeit not necessarily as well matched by subsequent commercialisation. This tradition has continued into the age of AI, in the form of growing numbers of AI SMEs and Universities. National competitions and innovation challenges present opportunities to harness the radical innovation and creativity emanating from the dynamic landscape of UK-based AI SMEs and universities, providing valuable complements to existing initiatives and closer collaborations with industry engagement and MNOs.

A

AI USE CASES

1/ Data

Title: Data as a service
Business Driver:
• Use Telco cloud for data storage, processing, analysis, and monetizing. • Massive data processing and storage can be costly to the operators. • Insights derived from data are similar from network to network, sharing such data and analysis across the network, among the operators and to the third party, can help with network maintenance, customer retention, and help Telco companies to transform to provide data-driven solutions
Benefit/What can AI do
• Cost saving. • Lower the barrier for AI model training as getting and processing data has been one of the first and major hurdles. • Provide a bundle of solutions – Telco transform to Techco
Challenges
• Data security and privacy issues. • No mature business model yet. • No mature framework to support data governance across the network (e.g. who owns the data?)
New opportunities
• The use of LLM for customer service is being explored/exploited by a majority of Telco operators, exposure of relevant data is an opportunity for Telco operators to diversify their services as they would now get insights of other networks (e.g., private networks dedicated to particular types of customers). • New revenue growth opportunities for Telco operators.

Title: Synthetic Data Generation
Business Driver:
• Data gathering and processing can be very costly and time consuming. • Not all the real network data are useful for specific purpose of optimisation, for example, for majority of the time there is no anomaly in the network therefore difficult to identify anomaly data to train an anomaly detection model for the network.
Benefit/What can AI do
• Most of the data gathered in the network is time-series data hence make the use of generative AI to create synthetic data feasible • Synthetic datasets can increase the proportion of edge cases / rare events, as well as generating data for scenarios that are theoretically possible but have not been observed in the live environment.
Challenges
• Generated synthetic data may not be fit for purpose – the efforts of validating if the synthetic data is feasible may outweigh the benefits. Alternatively, we could label and process data from real network, or sourcing data from a third party. • Trained AI model using synthetic data is good for initial trial but may not be suitable for large scale deployment of AI model.
New opportunities
• Synthetic data generation allows those without direct access to live network data the opportunity to develop AI products.

2/ Infrastructure and Operation

Title: 5G Core Performance and Power Savings
Business Driver:
• Software solutions with AI capabilities can be deployed at Core network to dynamically optimise server power consumption in real-time to match data traffic, ensuring energy efficiency without compromising critical performance metrics like throughput and latency. • NF autoscaling leveraging AI solutions to dynamically scaling up/down, in/out of the computational resources according to the changes of network traffic, while state-of-the-art solutions in existing cloud scaling, e.g., Kubernetes, does not monitor real time network traffic.
Benefit/What can AI do
• A recent MWC demonstration shows that the Intel Infrastructure Power Manager reference • Software delivers an average run time power savings of 30% while maintaining key Telco performance metrics by dynamically matching CPU power consumption to traffic. • Cost and energy saving.
Challenges
• Scalability of the AI solutions to the network – at the moment the solution is at the proof-of-concept stage.
New opportunities
• Leading to Telco network as a platform to jointly optimize connectivity and computational resources. • Optimise infrastructure.

Title: RAN Energy Saving
Business Driver:
• Increased network traffic demands have led to significant growth in energy consumption at the radio access networks, resulting in high network operation costs (OPEX). As a result, network operators are investing in new energy-saving features to achieve energy optimization in their network. ML technologies can be applied to the network to reduce the energy consumption at the base station in dense network deployments, for example, by allowing cells to be put in standby mode according to the dynamic network traffic.
Benefit/What can AI do
• Dynamically tune the cell on/off threshold according to real-time network usage. • Reduced energy consumption. • Reduced carbon footprint from the operators.
Challenges
• Pre-standard implementation, 3GPP and O-RAN discussions and specifications on this use case is still ongoing. • Fragmented solutions from different vendors, every vendor has their own solution implemented. • Potentially harming operator's network throughput as the result of cell on/off when AI not working properly.
New opportunities
• Extend of the use case to other part of the network in addition to RAN. • A compelling use case for achieving 6G KVI on sustainability. • AI capability to propose traffic optimisation options to reduce energy usage both current and forecast. • As RAN hardware becomes more configurable in energy states beyond on/off, enhance ML to use these granular energy states.

Title: Quality of Experience (QoE) optimistion
Business Driver:
• Latency and bandwidth demand of new applications such as cloud VR and industrial automation are not likely to be well served by semi static QoS configurations. • Introducing automated AI based control which reacts both to changing application demands, aggregate traffic usage on the cell and other dynamic radio condition changes, enables user experience expectation to be met and balanced with radio network efficiency.
Benefit/What can AI do
• Provide QoE metrics for the network. • Increase network performance for the applications in use at the time.
Challenges
• QoE is manifests in user applications executing on UE, which are remote from the AI controlling RAN configuration.
New opportunities
• Feedback QoE parameters to external elements to improve user experience, such as video codec to adjust video encoding scheme.

3/ Network Testing

Title: DevOps Acceptance Testing
Business Driver:
• Networks when delivered to Operators need to go through an acceptance testing regime. For physical networks this is a complex and resource intensive task. • As networks become more software based (SD-WAN, 5G core) and virtualised, changes can happen more frequently meaning that acceptance testing costs and capacity requirements will rise. • AI can contain this potential growth in cost and capacity demand, improve quality and relevance of the tests performed and make acceptance testing more responsive to known operational challenges.
Benefit/What can AI do
• AI can be used to define more discerning test cases. • When provided with feedback from operational experiences, AI can learn and adapt testing to more faithfully represent the reality of the network and the problems seen in operational networks. • This will lead to more resilient and secure network as problems are identified and remediated more quickly and consistently, before deployment to the operational network, and with audit trails.
Challenges
• Need training data from operation network to model that network with sufficient fidelity and select initial test cases. Ongoing continuous data feeds are needed as training data to keep models up to date. • Another challenge/requirement for Digital Twin representation of operational networks with consistent data schema and quality.
New opportunities
• The move to hybrid physical and virtualized network functions creates an opportunity for adapting current acceptance testing process and tools to incorporate DevOps best practice and tools. • Enhancement of current tools to incorporate AI reasoning based on historical training data and continuously fine-tuned using operational data. Digital twin concept has uses in the deployment pipeline beyond acceptance testing. This includes pre-training of models that underpin the software ready for the field. • This opportunity is very similar to inclusion of AI into Dev Sec Ops processes.

Title: Network Anomaly Detection

Business Driver:

- Test and monitoring of networks creates significant volumes of alerts and events.
- Processing these is complex and effort intensive.
- Current processes collect and analyse events, and then filter and groups them on temporal and graph dependency criteria.
- Improving more dynamic filtering and grouping of events is possible. With AI based reasoning, probable root cause analysis is a straightforward enhancement of current industry approaches.

Benefit/What can AI do

- AI can be used to enhance the current processes for collection, analysis, and root cause recommendations.

Challenges

- Very few barriers as opportunities are incremental on existing operational processes used by Operators and tools from vendors.
- Training data and feed could be an issue as the tools are already connected to the real time telemetry in the network.
- However, data schema and quality across multiple Network equipment providers is a known challenge.
- Volumes of telemetry data may also be a challenge as networks become more disaggregated and features such as mMIMO causes an explosion in the number of discrete components of the network. This is a strong driver for data collection and analysis to be more responsive to anomalies and impairments.

New opportunities

- Incremental opportunity that could be realized quickly that would provide foundation for move to Autonomous Networks based on Intent Based Network and Intent Interfaces. The required prescriptive analytics to enable this would be a progression from the diagnostic analytics that enables the root-cause analyses.

4/ Other Use Cases

Title: Overcoming GPS based location limitations.
Business Driver:
• Overcoming GPS based location limitations. • Current GPS location tracking technology struggles in urban areas where satellite signals are blocked by buildings. • The rollout of small cells and IoT sensors offers an opportunity to develop a new positioning system that could deliver millimetre-level accuracy in built environments using signals from cells and sensors with accurate geo-coordinates.
Benefit/What can AI do
• Improved navigation in mobile apps. • Improved navigation in autonomous (driverless) vehicle. • Cheaper and more accurate mapping tools.
Challenges
• Small cells and IoT sensors must have millimetre-level geo-coordinates (this will become easier as the new system rolls out and can be used for registering coordinates of hardware). • A new mobile technology is needed to poll nearby cells and sensors and use AI to accurately calculate the user's mobile device's location. Signal strength (or other parameters like latency) may be used for calculating coordinates in the early development stages, but ultimately a developed network of registered devices should be sufficient for AI to accurately predict coordinates as the new system rolls out.
New opportunities
• GPS technology currently used on mobile devices is notoriously inaccurate in built-up environments. Having a new mobile positioning system that delivers millimetre-level accuracy on mobile devices will facilitate innovators in creating a whole new range of geospatial products and solutions.

Title: Improving air quality in busy urban areas
Business Driver:
• This is a constant challenge for the government, but current initiatives, such as the ULEZ in London, are crude and are only loosely tied to actual emissions and air quality. The proliferation of IoT air quality sensors in urban areas offers an opportunity to rethink how emissions are controlled in urban areas by relaying live-sensor data to travellers and tying penalties and/or incentives to live air quality data in their proposed travel area.
Benefit/What can AI do
• Air quality in urban areas can be improved by restricting the number of vehicles allowed to travel into a high traffic area at any given time, based on current air quality data.
Challenges
• A new system needs to be designed for limiting the number of vehicles travelling to a designated area, based on current air quality IoT sensor data. Instead of a blanket zone fee to limit traffic, fees and restrictions should be tied to current air quality conditions in the target area. As traffic increases in a zone and the air quality degrades, higher fees are applied to vehicles entering the zone, with possible prohibition on entry to all but essential vehicles if the air quality degrades to a critical level. AI can be used to predict the impact on the overall air quality in a zone of each vehicle requesting entry to the zone.
New opportunities
Rather than just penalising motorists for travelling into restricted zones, incentives could be offered to change people's travel habits, such as offering cheaper fees for off-peak times (lower emissions, better air quality), or offering free public transport to regular travellers to a zone that is currently experiencing poor air quality due to high traffic.

Title: People safety in emergencies and disasters.
Business Driver:
• This is the number one priority when managing emergencies and disasters. • In doing so, it is important to make sure that no more people enter the affected area. Mobile phone users' approximate locations can be determined by the cells their phones have registered to and it would be easy to identify users that are travelling towards a dangerous area and to alert them to the danger and offer alternative routing.
Benefit/What can AI do
• AI can be used to identify mobile phone users in the vicinity of a dangerous area and determine their direction of travel using the history of cell registrations and deliver an alert to their device.
Challenges
Technically, this solution presents few challenges, but the main barrier will be regulatory as privacy concerns have to be addressed. It would need support from central government and legislation would likely be required that would allow such a system to place people safety above privacy concerns.
New opportunities
A solution that allows a disaster management agency to quickly create a digital geofence around a disaster area and push it out to all mobile network operators in seconds could save thousands of lives by alerting mobile phone users approaching the affected area to the danger and diverting them away from the danger, allowing emergency services to deal with those already in the area when the disaster occurred.

Title: Use of public infrastructure to host mobile telecoms equipment.

Business Driver:

- This is crucial to the rollout of 5G, 6G and future mobile technologies.
- Many factors are involved in identifying candidate street assets for hosting equipment and AI can play a key role in this process, thereby accelerating mobile technology rollouts.

Benefit/What can AI do

- AI image classifiers can identify 'clean' assets, i.e. assets with no other equipment attached. AI can assess the suitability of candidate assets in terms of site access (parking of works vehicles); nearby backhaul access; power connection availability; nearby obstructions (trees, tall buildings etc). MNO data from existing infrastructure can be used to train AI models to assess the efficacy of street assets and locations for hosting new equipment.

Challenges

- Existing public infrastructure datasets are either poor or non-existent and very few have high-resolution images of individual assets. Surveying of infrastructure to build a comprehensive dataset of street assets, with imagery, will be needed if AI is to be used to help accelerate mobile technology rollouts.
- Streamlining of the legal and commercial frameworks is essential to allow infrastructure providers to deploy equipment on public infrastructure. The recent DCIA program attempted to address this issue but fell short of providing a framework that could be adopted by councils.

New opportunities

- The time and cost investment required by MNOs, infrastructure providers, and council staff to make public assets available for hosting telecoms equipment currently ranges from painful to prohibitive.

- An opportunity exists, possibly with help/funding from the Geospatial Commission (which is funding the development of the National Underground Asset Register), to: build a national database of street assets; develop AI tools to identify suitable assets for hosting telecoms equipment; develop a marketplace with the necessary legal and commercial requirements for mobile infrastructure providers to acquire leases on public assets for equipment hosting.

B

Telco Data Requirements, Framework, and Standardisation

ITU-T Recommendation Y.3174 (02/2020)(122) “Framework for data handling to enable machine learning in future networks including IMT-2020”, identifies a set of ML data collection requirements, ML data output requirements and ML data processing requirements that are set in a context of addressing the challenges of diversity in network data sources; the need for network flexibility and agility; a multiplicity of applicable network configuration parameters and policies. This ITU-T Rec. Y.3174 also provides a high-level architectural components view of a data handling framework for ML.

The TM Forum has published a “AI Governance Toolkit”(123) that acts as a guidance for the safe and effective deployment of AI at scale for CSPs. The framework enables and demonstrates proper control and governance of an AI life cycle, from procurement to end of life, and helps to ensure that all internal stakeholders, external regulators, customers, and the general public are satisfied with how a CSP has operationalised and mechanised AI within the network.

The NGMN Alliance publication “Automation and Autonomous system Architecture Framework”(124) provides guidance and direction on an articulation of interoperable capabilities, enablers, and services, associated with network automation and autonomous systems. The document outlines a view on AI/ML models (e.g. Supervised / Unsupervised Learning), to be used in closed-loop decision making processes to provide a dynamic and adaptive capability for continuous enhancements in the end-to-end lifecycle management of networked systems.

(122) Y.3174 : Framework for data handling to enable machine learning in future networks including IMT-2020
(123) TM Forum AI Governance Toolkit
(124) NGMN Automation and Autonomous system Architecture Framework

C

Private Networks

While MNOs have traditionally focused on mobile broadband, recent years have seen a shift into new use cases, which could drive the next phase of growth in the industry. This started with Internet of Things (IoT), which serves large numbers of mobile devices sending small reports and commands. This is joined by Industrial IoT, with a need for very low latency and highly reliable communication for control of safety related processed. UAV support requires specific modification for airborne devices. Teams of emergency responders need push-to-talk facilities, backed by multicast protocols. These are only a few samples of an increasing list. The new use cases all share a need for new radio technology and associated AI to deliver efficient, scalable, flexible, operations. Whether adapted from existing systems or created as new bespoke networks, they will be designed and developed by highly skilled SME or dedicated business units within network equipment providers. This market is increasing in value, with network equipment vendors targeting an increasing proportion of revenue arising from these private networks. The operation of these specialist private networks will require new operations and maintenance practises and optimisations. There is an opportunity to apply AI to bring automation and high performance from the start, as an alternative to using manual process. The novel nature of the networks creates space for innovation in the AI deployments.

D

Satellite and other Non-Terrestrial Networks

Investment in satellite networks is rising rapidly, as the feasibility of satellite connection without large and specialised antenna on handsets has been realised. Iridium and Qualcomm have demonstrated short message (SMS) exchange over satellite link to a smartphone, known as direct-to-device service. Other smartphone manufacturers have made similar announcements which has brought in significant investment in this sector. It has also created credibility around satellite communications to low-cost devices, supporting narrow band communication.

Satellite networks present many new technical challenges, which presents an opportunity for the advanced research capability of the UK. As might be expected the satellite constellation serves radio connections with very different characteristics to traditional network. The constellations for direct to device are LEO, to minimise the signal power lost in transmission by minimising the distance between satellite and device.

However, unlike GEO satellites, LEO satellites track across the earth's surface rapidly, maintaining line of sight with devices for a maximum of 20 minutes before they move over the horizon. Devices cannot remain linked to the same cell for long, which drives a network topology. These new network topologies need new management algorithms, and there is scope to apply AI in these use cases. Operational procedures such as traffic steering, load balancing, and energy saving involve directing data traffic to appropriate cell to reach the device. While these are mature in terrestrial networks with their fixed cells, the additional challenge of moving cells will need to be automated and optimised with AI.

Satellite networks are generally greenfield developments, with massive investment, adopting the latest 5G technology and architectures, which presents opportunities for new entrants into the market.

The investment required to launch global satellite networks is in billions USD. Therefore, companies with this level of ambition have budget to invest in the right technologies to optimise the network performance. Without legacy systems and incumbent suppliers, the latest architectures are deployed supporting disaggregation, virtualisation, and AI. The disaggregation aspects allow smaller innovators to contribute and gain a foothold. This presents a perfect opportunity for UK based SME to make contributions.

Interested Readers are referred to the UKTIN NTN EWG paper on this topic.

E

Background on Network Testing

Testing is applied to the traditional network lifecycle. The first phase of this is the lab testing stage which originates with the vendors of the components of the network and can extend to the communication service provider or system integrator who often want to validate the selected mix of components prior to deployment in a live network. At this stage we can think of functional, interoperability, capacity, and performance tests. Functional test verifies that the components implement the specified and standardised interfaces correctly. Interoperability test verifies that two or more components are capable of working together over these interfaces. Capacity test establishes that the functionality prevails even when the components and systems h ave demands placed on them, for example from large numbers of subscribers, high bandwidth services, etc. Performance test verifies that the components and system are able to operate not just in a manner that conforms to specifications but is also able to do this with efficient use of resources, delivering target qualities of service for the desired levels of loading such that services can be delivered at scale.

Deployment testing takes place when the components of the network are deployed and can include for example testing that the components are operational, have the required power and cooling, radios are radiating on the right portions of spectrum and that the signal reaches the anticipated geographical areas. This also includes the fixed connectivity, and that the various transport and xHaul(125) network components have the target characteristics to support the radio in terms of latency, bandwidth, and jitter.

When the network is deployed and operational, testing is still needed and expands into assurance. The operator of the network will be interested in many aspects including whether there are impairments such as component failures or interruptions to the transport links. As the radio environment changes, the capacity and coverage will also change, and optimisation may be needed to bring this back to target. Beyond a network-centric view of the communication system, there are user- and service-centric views, and the service provider will be interested in what is the experience of the users, whether the services used by each subscriber achieves the quality expected, and thus whether the customer is satisfied or at risk of adverse outcomes such as churn.

(125) xHaul refers to the transport network that connects 4G/5G/6G radio access networks (RANs) to core networks

F

Ethics and Regulation

In this section various references are provided in tabular format to describe range of differing specifications on Ethic and Regulations.

The following tables provide several references and their ethic themes.

Turing/UK Gov	EU High Level EG	UNESCO
• Fairness • Accountability • Sustainability • Transparency	• Respect of human autonomy: • Prevention of harm • Fairness • Explicability	• Proportionality/Do No Harm • Safety/security • Fairness/non-discrimination • Sustainability • Privacy • Human oversight/determination • Transparency/Explainability • Responsibility/Accountability • Awareness/literacy • Multi-stakeholder & adaptive Governance

Microsoft	Deloitte	Stanford University
• Fairness • Reliability/Safety • Privacy/security • Inclusiveness • Transparency • Accountability	• Impact • Justice • Autonomy	• Privacy & Surveillance • Manipulation of Behaviour • Opacity of AI Systems • Bias in Decision Systems • Human-Robot Interaction • Automation and Employment • Autonomous Systems • Machine Ethics • Artificial Moral Agents • Singularity

Belmont Report	Other sources:
• Respect for Person • Beneficence • Justice	• US laws & regulation e.g. “AI Bill of Rights”, • NIST proposals, New York & California laws • Other big tech companies & consultancies, so not just Deloitte & Microsoft e.g. IBM, Accenture • Other universities with AI Ethics focus e.g. Cambridge Leverhulme Centre, Oxford AI Ethic centre, etc

G

UK Actions impacting Telecom AI Security

ITelecom is a critical infrastructure. Regulations and Security Act have impacts on the telecom use of AI. Here we gave a summary of the measures within the UK measures that have been taken:

- Telecommunications (Security) Act 2021 (legislation.gov.uk) which came into force in November 2021 that introduced a stronger security framework for providers of public electronic communications networks and services.
- Electronic Communications (Security Measures) Regulations and Telecommunications Security Code of Practice - GOV.UK (www.gov.uk) which has two in force security regulations that apply to use of AI in telecom and are cited by the UKTIN AI Security EWG:
- Electronic Communications (Security Measures) Regulations 2022 (ECSMR) These regulations mandate Telecom Providers to implement a risk assessment framework supported by measures to reduce risks and ongoing review of processes and preparedness measures. Detailed technical measures include security by design, monitoring and analysis, and security of supply chains. Organisation and governance measures include Board level security officer, competent staff, review and testing regimes, patching regimes, remediation measures, and information sharing.
- Telecommunications Security Code of Practice (TSCoP) Which sets out concepts and measures for managing telecom networks and are applied proportionately to different tiers of telecom providers based on turnover,
- The Data Protection Act 2018 governs data protection rights. Like GDPR, the DPA adopts a broad definition of personal information, encompassing some of the data available in the telecom industry.
- Using such data in training AI models needs to be compliant with the Data Protection Act 2018 and the UK GDPR.
- Guidelines for secure AI system development (ncsc.gov.uk) that sets out the best practices and is jointed published by the UK National Cyber Security Centre (NCSC), the US Cybersecurity and Infrastructure Agency (CISA) and 21 international government organisations.
- National Cyber Security Centre - NCSC.GOV.UK provides best practice and guideline to support UK businesses including telecom service providers. Notably 10 Steps to Cyber Security - NCSC.GOV.UK which includes NCSC-Vendor-Security-Assessment.pdf

H

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Abbreviations

Abbreviation	Detail
3GPP	The 3rd Generation Partnership Project
AI	Artificial Intelligence
AIX	AI Transformation
B2B	Business to Businesses
B2C	Business to Consumers
BSS	Business Support Systems
CAPEX	Capital Expenditure
CCTV	Closed Circuit Television
CMA	Competition & Markets Authority
CNI	Critical National Infrastructure
COTS	Commercial Off-The-Shelf
CPU	Central Processing Units
CRM	Customer relationship management
CSP	Communication Service Providers
DaaS	Data as a Service
DPU	Data Processing Units
ECSMR	Electronic Communications (Security Measures) Regulations 2022
ETSI	European Telecommunications Standards Institute
EWG	Expert Working Group
FTI	Future Telecoms Institute
GCP	Google Cloud Platform
Gen AI	Generative AI
GPUs	Graphics Processing Units
HBOM	Hardware Bill of Material
IaaS	Infrastructure-as-a-Service
IBN	Intent Based Networking
ICO	Information Commissioner's Office
IETF	Internet Engineering Task Force
IMT	International Mobile Telecommunications
ISG	Industry specification group
ITU	International Telecommunication Union
LCM	Life Cycle Management
MNO	Mobile Network Operators
MVPs	Developing Minimum Viable Products
NaaS	Network-as-a-Service
NCC	National Composites Centre
NEP	Network Equipment Provider
NFV	Network Functions Virtualisation
NGMN	Next Generation Mobile Network Alliance www.ngmn.org

Abbreviations Continued

Abbreviation	Detail
NTN	Non-Terrestrial Network
OECD	The Organisation for Economic Co-operation and Development
OPEX	Operational Expenditure
OSS	Operations Support System
PaaS	Platform-as-a-Service
PoC	Proof of Concepts
QoE	Quality of Experience
R&D	Research & Development
R&D&I	Research, Development, and Innovation
RAN	Radio Access Network
RIC	Radio Access Network (RAN) Intelligent Controller
ROI	Return on Investment
SaaS	Software-As-A-Service
SAI	Securing Artificial Intelligence
SBOM	Software Bill Of Material
SD-WAN	Software-Defined Wide-Area Networking
SDO	Standards Development Organisations
SME	Small & Medium-Sized Enterprises
SWOT	Strengths, Weaknesses, Opportunities, And Threats
TAM	Total Addressable Market
TCO	Total Cost Of Ownership
Techco	Technology Company
Telcos	Telecommunication companies
TIP	Telecom Infrastructure Project
TMF	TMForum
TRL	Technology Readiness Level
ULEZ	Ultra-Low Emission Zone
XDR	Extended Detection and Response
ZSM	Zero-touch network and Service Management

J

Version Control

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