Solution Brief

Addressing the Challenges of Future Green Networks

This solution brief provides an overview of Intel's technologies to tackle emissions in networks and address climate change.

Executive Summary

Intel's combination of leading-edge technology, trusted network expertise, and role in driving a standardized ecosystem have propelled the company to be a leader in 5G and a leading network silicon provider to the Information and Communications Technology (ICT) sector, which has an important role in tackling climate change.

Intel's continuing commitment to corporate responsibility is embedded in our purpose. With our 2030 corporate responsibility "RISE"[1] strategy and goals, we aim to create a more responsible, inclusive, and sustainable world, enabled through our technology and the expertise and passion of our employees. Intel continues to take actions to reduce our supply chain and global manufacturing climate footprint and to advance product energy efficiency.

From an operational perspective, the primary source of emissions is generated from electricity used in powering the network[2]. This dominates emissions from network products.

Emission reduction targets for mobile and fixed networks have been calculated by the International Telecommunication Union (ITU). These science-based targets (SBT) provide guidance to the sector that meets the International Panel on Climate Change (IPCC) goal of 1.5ºC for 2030.[3]

Renewable energy is an essential strategy adopted by operators to reduce emissions, but it is not a complete solution and presents several challenges related to availability in some markets, variability, and grid modernization. Product efficiency is essential to meet sector emission targets, curb energy use, and tackle energy costs.

In addition, the application of technology to improve efficiency in high emission sectors such as energy, transport, and agriculture is a priority.

This document is part of the Network Transformation Experience Kit, which is available at https://networkbuilders.intel.com/network-technologies/network-transformation-exp-kits.

Introduction

Energy and Network Emissions

Excluding user devices, the primary source of emissions from network products is the electricity required to power the network during operation lifetime. This "Product in Use" category of operational carbon dominates emissions from network products.

While the overall emissions footprint of ICT is small, (2%-4% of global emissions)[4], sector targets for emissions reduction in mobile and fixed networks are required. These have been calculated by the ITU and these science-based targets provide guidance on emission reductions in accordance with the IPCC, 1.5ºC climate goal for 2030.

Network Energy Challenges

The challenge for networks is to reduce global emissions in an environment of consistent year on year data growth, which increased by 42% in mobile networks in 2021[5].

While 5G networks are designed to be more spectrally efficient than previous generations, the additional equipment such as mMIMO antennas and the spectrum allocated have the potential to increase overall power use in the network[6].

Energy costs are an important element of operator OPEX so, notwithstanding emissions, cost is a driver of network energy efficiency.

Renewable energy is an essential strategy adopted by operators to reduce emissions, but it is not a complete solution and presents several challenges related to market availability and variability. National transmission grids designed for traditional generation need considerable investment to handle renewables such as wind and solar. This is a complex transition with a range of stakeholders that will take considerable time.

Solution and Technologies

Product Efficiency

Intel has provided incremental investment over the previous generations of Intel® products to offer one of the most complete portfolios of network solutions for the industry and Intel's technology is widely deployed across the core network, access network, and smart edge. In recent years, virtualization, containerization, and cloud networking have transformed the industry. Network functions are now deployed on a wide range of volume x86 servers underpinned by Intel technologies and commercial operating system offerings. This broad, robust software and hardware ecosystem enable the use of mainstream power saving features focused on increasing performance, optimizing power consumption, and decreasing latency for time-sensitive applications.

Power and Resource Management Technologies

Modern processors, though the Advanced Configuration and Power Interface (ACPI)[7], provide management of core and package sleep states (C-states) along with fine grained control of core frequency (P-states) to optimize power consumption to match traffic load. The following paper provides an overview of the power management features in 3rd Generation Intel® Xeon® Scalable processors: https://builders.intel.com/docs/networkbuilders/power-management-technology-overview-technology-guide.pdf

Recent generations of processors have included improvements to ensure that network service level agreements (SLAs) around latency and packet loss are kept when actively using power management. The paper at the following link provides examples of the use of frequency transition improvements that support network SLAs: https://networkbuilders.intel.com/solutionslibrary/power-management-enhanced-power-management-for-low-latency-workloads-technology-guide

Closed Loop Power Management with AI

Network traffic is variable by location and time of day. While the underlying processor technologies are fundamental to managing the platform power, there are several software layers required to build such a closed loop power management solution stack. Figure 1 shows the Intel CPU power management technologies, platform telemetry, monitoring, and analytics systems with an orchestration layer to allow action based on the analysis. Telemetry from the platform can be organized into user-defined reports that can provide insights and drive closed loop orchestration decisions. For example, during low traffic periods, workloads can be consolidated and frequency scaling or sleep states can be utilized to reduce power without impacting the SLA.

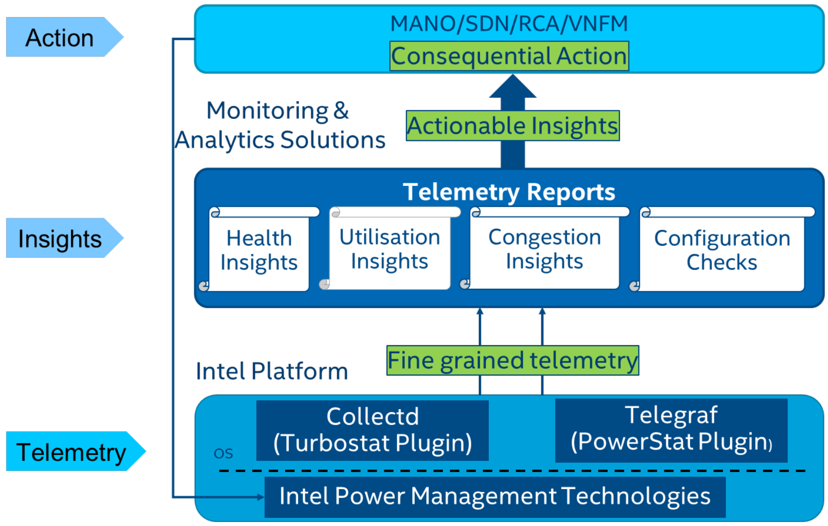

Figure 1. Component Power Management, System Telemetry, Monitoring, and Analytics Systems with an Orchestration Layer

Speed Select Technology - Base Frequency (Intel® SST-BF) and Intel® Resource Director Technology (Intel® RDT) for multi-tenant network-sliced workloads to demonstrate significant energy improvements. https://networkbuilders.intel.com/solutionslibrary/intel-technologies-for-resource-tuning-energy-efficient-network-slices

Network Locations

Radio Access Network

The radio access network (RAN) comprising base station, active antenna units, and backhaul can consume 60-80%[8] of energy in the network. Operator initiatives such as network planning, spectrum management, site level renewables, and product/technology refreshes are one part of the solution. In addition, other areas such as radio and product features provide additional opportunities for power saving such as symbol, channel, or carrier sleep modes along with accelerated processor instructions and baseband pooling via Cloud RAN solutions.

In addition to operator initiatives, areas such as radio and product features provide opportunities for power saving.

- 3rd Generation Partnership Project (3GPP) Standards: Within the current standards, various techniques for automatic wake-up/sleep modes including shutdown on, symbol, channel, or carrier can be used.
- Massive Multiple Input Multiple Output (mMIMO): The digital processing components within the mMIMO/active antenna unit (AAU) and power amplifier need capabilities at the silicon level to manage power dynamically according to load. The complexity of the real-time radio environment and end user customer experience may need to be managed using machine learning/artificial intelligence (ML/AI) techniques[9].
- Centralized/Virtualized RAN (Cloud RAN): These solutions allow a more predictable average load to be power managed on a standard server environment across multiple remote radio units.
- Application and Baseband Processing: Processor developers continuously create instructions that applications can use to increase performance. Examples of such instructions[i] include Intel® Advanced Encryption Standard New Instructions (Intel® AES-NI), Intel® Advanced Vector Extensions 512 (Intel® AVX-512), and Vector Neural Network Instructions (VNNI) for artificial intelligence. For power savings, instructions such as MWAIT, MONITOR, PAUSE, and UMWAIT are part of the CPU's suite of capabilities that allow the CPU to enter low power C-states.

Intel FlexRAN is a software development kit and enablement program for commercial 5G base stations in the RAN and edge. https://builders.intel.com/docs/networkbuilders/virtual-ran-vran-with-hardware-acceleration.pdf

The complexity of radio solutions is considered a fertile ground for ML/AI applications to optimize performance. For example, intelligent 5G L2 MAC Scheduler network performance in terms of spectral efficiency, quality of service (QoS), and network resource utilization demonstrated ~15% improvement in network performance leveraging Intel AI software, Analytics Zoo. https://builders.intel.com/docs/networkbuilders/intelligent-5g-l2-mac-scheduler-powered-by-capgemini-netanticipate-5g-on-intel-architecture-v13.pdf

Core Network and Data Centers

Over the last decade, core networks have moved away from dedicated appliances and time division multiplex (TDM) networks to an all-IP virtualized environment on volume x86 servers with optical site interconnect. They can be hosted in large data centers with dedicated power and cooling solutions, substantially improving efficiency[10]. This allows the full range of power management, telemetry, and processor power saving features to be deployed

Intel® Network Builders ecosystem partner Intracom Telecom has used its solution to predict VNF traffic levels and dynamically adjust the frequencies of processor cores used by Data Plane Development Kit (DPDK)-based VNFs according to their incoming load. Power consumed by the system was reduced by 14% on average, and up to 35%, over a 24-hour period. For more information, see, *Intracom Telecom Machine Learning Boosts NFV Energy Efficiency*, https://builders.intel.com/docs/networkbuilders/intracom-telecom-machine-learning-boosts-nfv-energy-efficiency.pdf

Intel's IT team reduced data center power usage effectiveness (PUE) to an outstanding 1.06 via disruptive server technologies as part of an environmental-responsible strategy. This also reduces waste and water use are detailed in *Green Computing at Scale*, https://www.intel.com/content/www/us/en/it-management/intel-it-best-practices/green-computing-at-scale-paper.html

Enabling Impact at the Smart Edge

The concept of edge computing is to move the processing power closer to the end user to facilitate low latency critical applications. Intel® Smart Edge Open is an edge computing software toolkit that enables customers to build platforms optimized for the edge with power management features an integral part. Details can be found here, https://www.intel.com/content/www/us/en/developer/tools/smart-edge-open/overview.html

Enabling impact is defined as the cost (in emissions terms) of deploying a technology solution to reduce the overall footprint of a service. Intel partners with a robust ecosystem of equipment manufacturers and systems integrators to deliver a new generation of smart solutions built on interoperable, secure, and scalable Internet of Things technologies and advanced data analytics for industries in high emissions sectors such as energy, manufacturing, transport, and agriculture.

For example, in collaboration with Iberdrola, the distribution of advanced computing capabilities onto different nodes of the electricity grid (in this case, secondary substations) represented a significant step in the digitalization of the distribution grid. For more information, see https://www.iberdrola.com/innovation/edge-computing-electricity-grid and https://www.intel.com/content/www/us/en/energy/energy-overview.html

Addition resources are available via the Digital Climate Alliance

Summary

Intel's continuing commitment to corporate responsibility is embedded in our purpose. With our 2030 corporate responsibility "RISE" strategy and goals, we aim to create a more responsible, inclusive, and sustainable world, enabled through our technology and the expertise and passion of our employees.

As a leader in 5G and a leading silicon provider to the industry, Intel has an important role in improving the energy efficiency and sustainability of networks around the world.

In this solution brief, we outline a range of features and technologies and provide examples of the deployment of these technologies across all areas of the network, RAN, core, data center, and smart edge.

The use of technology to address the emissions footprint of high impact industries such as energy, manufacturing, transport, and agriculture is key to reducing emission in these sectors.

Terminology

Table 1. Terminology

ABBREVIATION	DESCRIPTION
3GPP	3rd Generation Partnership Project
AAU	Active Antenna Unit
ACPI	Advanced Configuration and Power Interface
CPU	Central Processing Unit
CRAN/VRAN	Cloud and/or Virtualized RAN
DPDK	Data Plane Development Kit
ICT	Information and Communications Technology
IPCC	International Panel on Climate Change
ITU	International Telecommunications Union
ML/AI	Machine Learning/Artificial Intelligence
mMIMO	Massive Multiple Input Multiple Output (Antenna)
OPEX	Operational Expenditure

ABBREVIATION	DESCRIPTION
PUE	Power Usage Effectiveness
QoS	Quality of Service
RAN	Radio Access Network
SLA	Service Level Agreement
TDM	Time Division Multiplex
VNF	Virtual Network Function

References

1. Intel Corporate Responsibility: https://www.intel.com/content/www/us/en/corporate-responsibility/corporate-responsibility.html
2. Malmodin, Jens & Lundén, Dag. (2018), The Energy and Carbon Footprint of the Global ICT and E&M Sectors https://www.mdpi.com/2071-1050/10/9/3027/pdf
3. Guidance for ICT Companies. (pp 9) https://sciencebasedtargets.org/resources/legacy/2020/04/GSMA_IP_SBT-report_WEB-SINGLE.pdf
4. The climate impact of ICT: A review of estimates, trends and regulations. https://arxiv.org/ftp/arxiv/papers/2102/2102.02622.pdf
5. Ericsson Mobility Report Q3 2021 https://www.ericsson.com/en/reports-and-papers/mobility-report
6. ETSI ES 203 700. Sustainable power feeding solutions for 5G: https://www.etsi.org/deliver/etsi_es/203700_203799/203700/01.01.01_60/es_203700v010101p.pdf
7. Advanced Configuration and Power Interface (ACPI) Specification," [Online]. Available: https://uefi.org/specs/ACPI/6.4/
8. Going green: Benchmarking the energy efficiency of mobile, GSMA, https://data.gsmaintelligence.com/research/research/research-2021/going-green-benchmarking-the-energy-efficiency-of-mobile
9. ITU: Smart Energy Saving of 5G Base Station: Based on AI and other emerging technologies to forecast and optimize the management of 5G wireless network energy consumption. https://www.itu.int/en/ITU-T/focusgroups/ai4ee/Documents/TR-D.WG3_02-Smart%20Energy%20Saving%20of%205G%20Base%20Station%20Based%20on%20AI%20and%20other%20emerging%20technologies_Tan.pdf
10. IEA Data Center and Data Transmission Networks, November 2021, https://www.iea.org/reports/data-centres-and-data-transmission-networks

Table 2. Additional References

TITLE	SOURCE
Power Management – Technology Overview Technology Guide	https://builders.intel.com/docs/networkbuilders/power-management-technology-overview-technology-guide.pdf
Power Management – Enhanced Power Management for Low-Latency Workloads Technology Guide	https://networkbuilders.intel.com/solutionslibrary/power-management-enhanced-power-management-for-low-latency-workloads-technology-guide
Intel Technologies for Resource Tuning Energy Efficient Network Slices Technology Guide	https://networkbuilders.intel.com/solutionslibrary/intel-technologies-for-resource-tuning-energy-efficient-network-slices
Virtual RAN (vRAN) with Hardware Acceleration White Paper	https://builders.intel.com/docs/networkbuilders/virtual-ran-vran-with-hardware-acceleration.pdf
Intelligent 5G L2 MAC Scheduler	https://builders.intel.com/docs/networkbuilders/intelligent-5g-l2-mac-scheduler-powered-by-capgemini-netanticipate-5g-on-intel-architecture-v13.pdf
Intracom Telecom Machine Learning Boosts NFV Energy Efficiency White Paper	https://builders.intel.com/docs/networkbuilders/intracom-telecom-machine-learning-boosts-nfv-energy-efficiency.pdf
IT@Intel: Green Computing at Scale White Paper	https://www.intel.com/content/www/us/en/it-management/intel-it-best-practices/green-computing-at-scale-paper.html

TITLE	SOURCE
Intel® Smart Edge Open	https://www.intel.com/content/www/us/en/developer/tools/smart-edge-open/overview.html
Edge Computing on the Electricity Grid	https://www.iberdrola.com/innovation/edge-computing-electricity-grid
Enabling Smart Energy and Energy IoT	https://www.intel.com/content/www/us/en/energy/energy-overview.html

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[i] Instruction sets may vary by product and generation.