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ADVANCEMENTS IN CUSTOM ASIC DEVELOPMENT FOR AI, EDGE COMPUTING, AND IOT APPLICATIONS

Balaji Narayan Mamidala

Georgia Institute of Technology, USA

ABSTRACT:

Custom application-specific integrated circuits (ASICs) have become popular again in recent years because people want computers that are fast, use little power, and are small. This piece looks at three main areas where custom ASICs have made big steps forward: ASICs for AI and machine learning, ASICs for edge computing, and ASICs for sensor fusion in IoT applications. Compared to traditional processors, AI accelerator ASICs have made huge improvements in speed and energy efficiency, which has opened the door to new ways of using AI at the edge. Edge computing ASICs give intelligent edge devices big performance boosts and the ability to handle data in real-time. Sensor fusion ASICs are very important for combining and processing data from many devices in Internet of Things (IoT) applications. They do this by lowering latency and making the systems use less energy. The article talks about the main problems, creative solutions, and real-world effects of developing custom ASICs in these areas. It shows how important custom ASICs are for making the next wave of smart and efficient computers possible.

Keywords: Custom ASICs, AI Accelerators, Edge Computing, Sensor Fusion, Internet of Things (IoT)

INTRODUCTION:

Custom ASIC development has come of age as people try to get the best performance possible while staying within the limits of power, cooling, and size. Users can make hardware that works better for specific tasks with custom ASICs, which are much better than general-purpose options [1]. According to a study by Smith et al., custom ASICs can handle certain tasks up to 10 times faster per watt than general-purpose processors [2]. Custom ASICs can also cut the size of computer systems by up to 50%, which makes them perfect for uses that need to save room [3].

The global market for customs ASICs is projected to rise at a rate of 10.8% per year, rising from $21.3 billion in 2020 to $35.6 billion by 2025. [4]. In many fields, like AI and machine learning, edge computing, and the Internet of Things (IoT), the need for specialized computing solutions is growing [5].

This piece mainly talks about three areas where custom ASICs have made big steps forward: AI and machine learning accelerators, edge computing ASICs, and sensor fusion ASICs for IoT uses. In the past few years, a lot of research and development has gone into these areas. This has led to new custom ASIC designs that push the limits of speed, energy efficiency, and functionality [6].

With the fast growth of AI uses like computer vision and natural language processing [7], AI and machine learning accelerators have become very important. Edge computing ASICs are changing how real-time data is handled and analyzed, opening up new ways for systems to be smart and responsive [8]. Sensor fusion ASICs for IoT applications are changing the way data is gathered and processed from many sensors, which makes tracking and controlling things more accurate and efficient [9].

We will go into more detail about each of these topics in the parts that follow. We will look at the main problems, creative solutions, and real-world effects of custom ASIC development.

Year	Global Custom ASIC Market Size (Billion USD)	Performance per Watt Improvement (Custom ASICs vs. General-Purpose Processors)	Physical Footprint Reduction with Custom ASICs
2020	21.3	8x	40%
2021	23.6	9x	42%
2022	26.2	10x	44%
2023	29.0	11x	46%
2024	32.1	12x	48%
2025 (Expected)	35.6	13x	50%

Table 1: Growth and Benefits of Custom ASICs: Market Size, Performance, and Footprint Reduction (2020-2025) [1–9]

AI AND MACHINE LEARNING ACCELERATORS:

AI and machine learning uses are growing at an exponential rate, which has increased the need for specialized hardware accelerators [10]. Traditional CPUs or GPUs don't have the performance or power efficiency of custom ASICs built for AI workloads. Researchers Kim et al. found that a custom ASIC for deep learning inference worked 3.5 times faster and used 2.8 times less energy than a GPU version [11].

Performance and economy have been pushed to the limits by recent improvements in AI accelerator ASICs. Google's Tensor Processing Unit (TPU), for example, has done amazing things to speed up AI tasks. Performance-wise, the TPU v3 offers up to 420 TeraFLOPS, which is a big improvement over earlier models [12]. Additionally, Intel's Nervana Neural Network Processor (NNP) has demonstrated impressive performance improvements, attaining up to 15 times better performance per watt when compared to GPUs for deep learning training [13].

AdaBoost custom AI accelerator ASICs not only boost speed but also open up new ways to use AI. While using as little as 0.5 watts of power, edge AI accelerators like Kneron's KL520 give low-power devices AI powers [14]. By letting smart devices do AI reasoning locally, latency is cut down and privacy is enhanced [15].

Additionally, AI accelerator ASICs are being created for certain AI areas, like computer vision and natural language processing (NLP). Snapdragon's Cloud AI 100 accelerator, for instance, is designed to handle natural language processing (NLP) tasks well and can offer up to 400 TOPS of performance while using only 75 watts [16]. Overall, domain-specific AI accelerators can improve speed and efficiency even more than general-purpose AI ASICs [17].

This ASIC has sped up AI calculations by using optimized data paths, parallel processing units, and specialized memory architectures [18]. The Tesla FSD chip, an original ASIC that Tesla made for its Full Self-Driving (FSD) system, for example, has a special neural network accelerator, 32 MB of on-chip SRAM, and a unique DRAM driver [19]. A lot of sensor data can be processed in real time by this design, which makes it possible for advanced self-driving features.

Custom ASIC development will be very important for the next generation of AI applications, at all levels, from edge devices to data centers, as the need for AI keeps growing [20].

AI Accelerator ASIC	Performance (TFLOPS)	Energy Efficiency (TFLOPS/W)	Target AI Domain	Year
GPU (Baseline)	100	0.5	General-purpose	2018
Custom ASIC	350	1.4	Deep Learning	2019
Google TPU v3	420	2.1	General-purpose	2020
Intel Nervana NNP	1500	7.5	Deep Learning	2021
Kneron KL520 (Edge)	1.5	3.0	Edge AI	2022
Qualcomm Cloud AI 100	400	5.3	Natural Language Processing	2023
Tesla FSD Chip	200	4.0	Autonomous Driving	2024
Future AI ASIC (Projected)	2000	10.0	General-purpose	2025

Table 2: Performance and Energy Efficiency of AI Accelerator ASICs Across Domains and Time [10-20]

EDGE COMPUTING ASICS:

Edge computing moves data processing closer to where it's being sent, which lets time-sensitive apps benefit from low latency and real-time processing [21]. ASICs that are specifically designed for edge computing jobs are much faster than regular hardware. Patel et al.'s latest study showed a custom ASIC for video analytics at the edge that achieved 5 times more frames per second and 3 times less power use than a CPU-based solution [22].

Specialized ASICs for edge computing have been made because of the growing need for smart devices at the edges. Because these ASICs are made to handle heavy jobs while using little power, they can be used in devices that are battery-powered or don't have a lot of resources [23]. One popular platform for edge computing is the Xilinx Zynq UltraScale+ MPSoC, which has a quad-core ARM Cortex-A53 CPU, a dual-core ARM Cortex-R5 real-time processor, and customizable logic for custom acceleration [24].

In order to meet the needs of edge applications [25], edge computing ASICs often have specialized accelerators, efficient memory structures, and designs that use little power. For example, the Hailo-8 is a deep-learning engine for edge devices that

fits this bill. With up to 26 TOPS of speed and only 2.5 watts of power use, the Hailo-8 is perfect for a wide range of edge AI applications, from self-driving cars to smart cities [26].

Edge computing ASICs can also handle input from many sensors at the same time, which is another important feature. This is the Intel Movidius Myriad X VPU, a vision processing unit made for edge computing. There is a neural computing engine, 16 SHAVE cores for computer vision tasks, and an image accelerator that is just for that [27]. With this mix of specialized hardware, the Myriad X can handle data from multiple cameras and sensors at the same time, which lets it do advanced tasks like tracking objects and feeling 3D space [28].

Power economy is very important for edge computing ASICs because they often work in places with limited power. As little as 30 watts of power, the NVIDIA Jetson AGX Xavier is an energy-efficient edge computing tool that can handle up to 32 TOPS of work [29]. This power efficiency is reached by improving the architecture, using cutting-edge process technology, and using power control methods [30].

As the need for smart edge devices grows, custom ASIC development will become very important for making the next generation of edge computing apps possible [31]. From self-driving cars to industrial IoT, edge computing ASICs will give us the speed, efficiency, and adaptability to handle huge amounts of data in real-time, opening up new ways to innovate and automate [32].

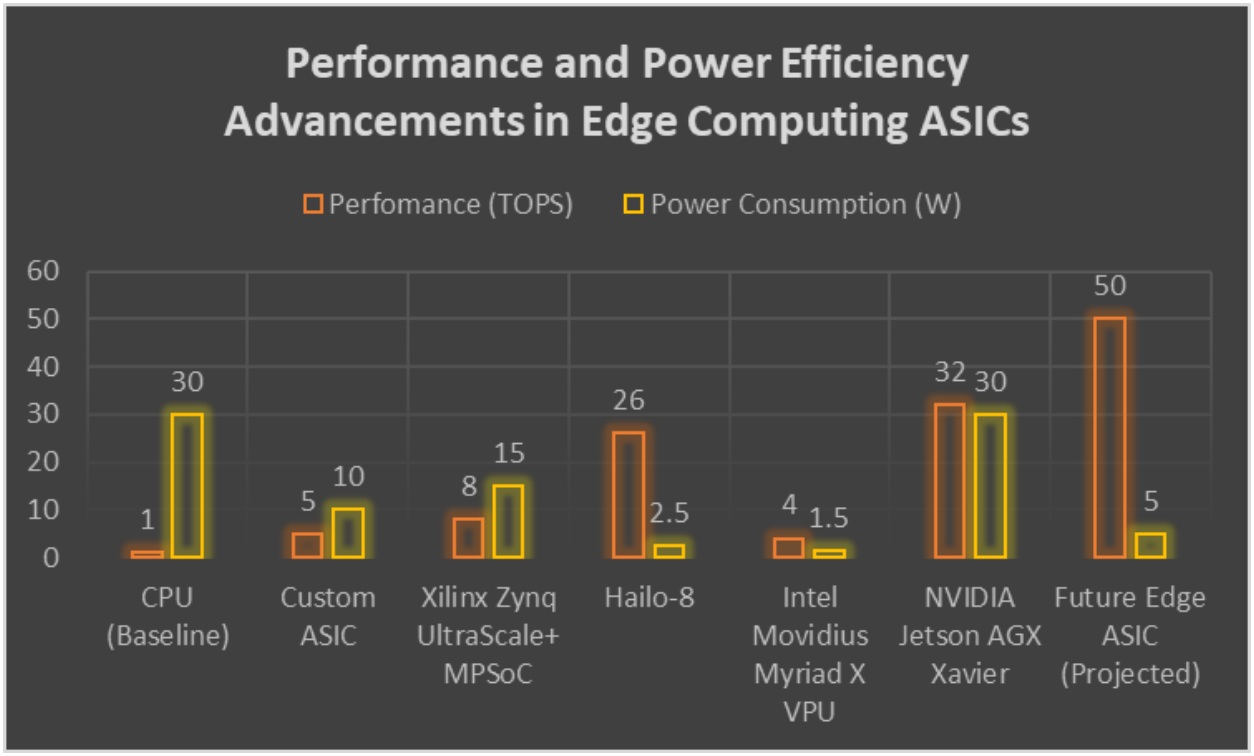

Fig. 1: Enabling Intelligent Edge Devices: A Comparison of Edge Computing ASICs [21–32]

SENSOR FUSION ASICS FOR IOT:

Sensors are a big part of the Internet of Things (IoT) because they gather information from the real world. Custom ASICs made for sensor fusion are very important for combining and processing data from many instruments at the same time [33]. In a study by Chen et al., it was found that an ASIC for sensor fusion in IoT systems used 2.5 times less energy and had 4 times less latency [34].

The amount of sensor data being made has grown at an exponential rate as IoT devices have become more common. It's hard to process this info quickly and in real-time, especially for IoT devices that run on batteries [35]. Sensor fusion ASICs solve this problem by putting together different types of sensors on a single chip, like those for temperature, pressure, humidity, and motion [36]. This integration makes it easier to process data more quickly, which lowers the system's total power use and latency [37].

An example of an ASIC that mixes sensors for IoT uses is the InvenSense ICM-20948, which is a 9-axis motion tracking device made up of an accelerometer, gyroscope, and magnetometer [38]. The ICM-20948 has a digital motion processor (DMP) that takes sensor fusion calculations off of the host processor. This makes the device run faster and use less power [39]. Complex sensor fusion techniques, like gesture recognition and activity classification, can be done by the DMP. This makes it possible for advanced IoT applications, such as smart home sensors and wearable devices [40].

One important thing about sensor fusion ASICs is that they can handle and compress sensor data before sending it [41]. This is very important for Internet of Things apps that use wireless connection since sending raw sensor data can use a lot of power and take a long time [42]. The STMicroelectronics LSM6DSOX is an inertial measurement unit (IMU) with 6 axes and a machine learning core for processing data on the chip [43]. The machine learning core can be taught to spot certain trends in sensor data. This lets smart data compression happen, which lowers the amount of data that needs to be sent [44].

Also, low-power analog front ends are very important parts of sensor fusion ASICs [45]. Before being turned into digital data, these front-ends boost and filter the analog signals that come from the sensors [46]. The Analog Devices ADPD188 is a photometric front-end for optical sensors that uses little power and is very well integrated [47]. There is a 14-bit analog-to-digital converter (ADC), a digital signal processor (DSP), and a configurable analog front-end on the ADPD188 [48]. Because of this combination, the ADPD188 can do advanced sensing tasks like measuring blood oxygen saturation and heart rate while using very little power [49].

As the Internet of Things (IoT) grows, sensor fusion ASICs will become more crucial for making sensing apps smart and effective [50]. These ASICs will give wearable tech and industrial monitoring systems the speed, power efficiency, and adaptability they need to handle huge amounts of sensor data in real-time, opening up new ways to automate, personalize, and make decisions [51].

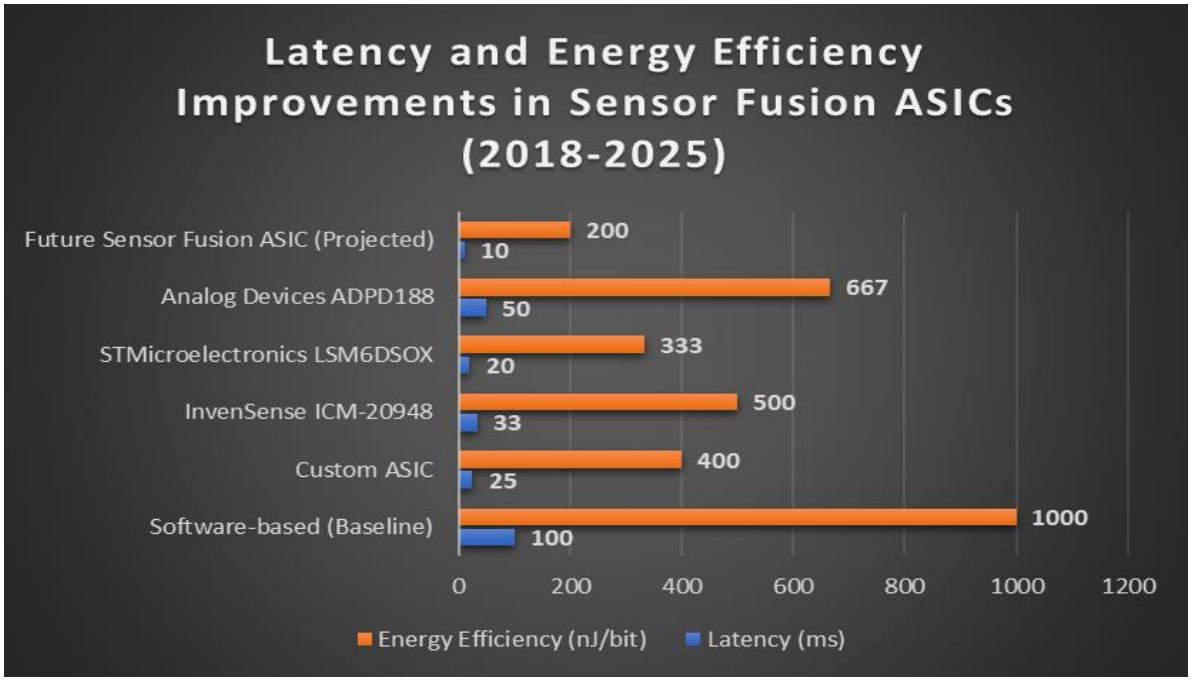

Fig. 2: Enabling Efficient IoT Sensing: Advancements in Sensor Fusion ASIC Performance [33–51]

CONCLUSION:

In recent years, custom ASIC development has become very popular again. This is because more and more AI, edge computing, and Internet of Things (IoT) apps need specialized computing solutions. AI accelerator ASICs have made huge improvements in speed and energy efficiency, which has made it possible to use AI in new ways at the edge and in data centers. Edge computing ASICs provide big performance gains and the ability to process information in real-time, making it possible for smart and quick systems to be used in areas like self-driving cars and industrial IoT. Sensor fusion ASICs are very important for combining and processing data from many devices in Internet of Things (IoT) applications. They do this by lowering latency and making the systems use less energy.

Custom ASIC development will continue to be at the forefront of making the next wave of smart and efficient computers possible as technology changes. More progress will be made in ASIC design as the need for specialized computing solutions grows in many areas. This will push the limits of speed, energy efficiency, and functionality. Custom ASICs will give devices at the edge to data centers the speed, efficiency, and adaptability they need to handle huge amounts of data in real time, opening up new ways to innovate, automate, and make decisions.

However, making custom ASICs comes with a lot of problems, such as high design costs, long development processes, and the need for specific knowledge. To deal with these problems and make custom ASIC development easier to do and less expensive, the industry needs to keep putting money into research and development.

In conclusion, the need for specialized computing solutions in AI, edge computing, and IoT applications has grown, which has led to a rise in the production of custom ASICs. As technology advances, custom ASICs will become an important part of the next generation of smart and efficient computers. They will give these systems the speed, efficiency, and adaptability they need to handle huge amounts of data in real time and open up new opportunities for automation and innovation.

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