**Research on at least 5 trends in microprocessors or microcontrollers., specify the key proponent/s, timeline, and applications. Provide data in terms of figures and tables. Cite at least 5 references using APA v7.**

1. **INTEGRATION OF AI/MACHINE LEARNING ON MICROPROCESSORS**

With the current trend with regards to Artificial Intelligence (AI) and Machine Learning, modern microprocessors as well as Microcontroller Units (MCU) have utilized the aforementioned technology in order to accelerate computing time and accomplish more processes quicker. By default, processors are able to accomplish processes “serially.” The utilization of “context-switching” (a processor technique utilized in order to efficiently change processes according to a process’ criticality while saving the state of a previous process) makes it seem that processors are multi-tasking threads and processes where in reality, it is actually the opposite. Through the integration of AI technology and Machine Learning on modern processors (as well as graphics processing units), actual parallelism and enhance pipelining is achieved.

The first proponent of artificial intelligence would be Alan Turing. On his paper entitled, “Computing Machinery and Intelligence” which was published in the year 1950, Alan Turing formulated the “Turing test” of which determines if a machine has the capacity to think on its own. In 1956, John McCarthy held a conference in Dartmouth College in New Hampshire, USA. The conference is now considered the actual founding of the term Artificial Intelligence (AI). He discussed how machines can learn to use abstract languages such as machine code and even natural language while aiding humans in the process to simplify significant tasks (Lawrence Livermore National Library, n.d.). Years after the formal definition of AI, numerous individuals have formulated AI technology in either emulating human decisions or utilizing rapid decision making to accelerate process accomplishment. A dissertation from James Robert Slagle further pushed the industry. His dissertation entitled, “A Heuristic Program that Solves Symbolic Integration Problems in Freshman Calculus” introduces SAINT. SAINT or Symbolic Automatic Integrator was a heuristic program that Slagle formulated in order to emulate the decision-making of a freshman student in solving integral calculus problems (AIWS, 2025).

After SAINT, research on Artificial Intelligence slowed down. However, the 1990’s and onwards presented an uptrend in AI research and development with more emphasis on data-heavy and specific issues instead of human emulation (Lawrence Livermore National Library, n.d.). This applies to modern microprocessors that utilizes AI to accelerate its computing power. The development of AI can be directly correlated to the rapid innovation of microprocessors. By this time, multiple AI models have been formulated for specific tasks or accelerating output. Despite the commendable sequential speed of microprocessors during the 2010’s, it could only improve performance up to a certain extent. The aforementioned AI models were to taxing to run and required much computational power in order to be ran properly in real time (Khan, Pasha, & Masud, 2021). In response to this, microprocessor companies have embedded deep learning algorithms and hardware on their microchips in order to combat this bottleneck. Intel formulated the Math Kernel Library and integrated “Intel Deep Learning Boost Library” on their processors for improved real time performance for AI models. Through Intel DL Boost Library, various AI models for speech recognition, object detection and other AI model specific tasks were vastly improved (Khan, Pasha, & Masud, 2021).

Executing AI models are parallel in nature. No matter the implementation of deep learning and machine learning on microprocessors, its sequential nature would never reach to levels of which it could be considered efficient. Graphics Processing Units run in parallel at its core. NVDIA took advantage of this fact and developed a library entitled “Compute Unified Device Architecture (CUDA)” with graphics cards that would render them compatible with this technology. NVDIA also formulated Tensor Cores which are specific microprocessors on their graphics cards that would aid in AI models and machine learning. This would ultimately be utilized for creating graphics cards fluent not only for graphics processing but for machine learning and other intensive AI models as well (Khan, Pasha, & Masud, 2021).

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| --- | --- | --- | --- | --- | --- |
| **CPU** | | | **GPU** | | |
| **Processors** | **Minimum Cores** | **Maximum Cores** | **Processors** | **Tensor Cores** | **CUDA Cores** |
| Intel i7, 10th Gen | 4 | 8 | NVIDIA RTX 2080 | N/A | 4352 |
| AMD Ryzen | 4 | 16 |
| Intel Core i9, 10th Gen | 8 | 28 | NVIDIA V100 | 640 | 5120 |
| Intel Xeon Plat. I Gen | 4 | 28 |
| Intel Xeon Plat. II Gen | 4 | 56 | NVIDIA A100 | 432 | 6912 |
| AMD Ryzen Threadripper | 24 | 64 |

Figure 1.1: CPU vs GPU Cores (Khan, Pasha, & Masud, 2021)

The figure presents the core counts of modern CPU vs modern GPUs. It presents how compatible GPUs are to machine learning and AI especially with the integration of specific microprocessors that handle AI model execution and deep learning. It can be observed that compared to the number of cores of a processor, GPUs are exponentially more capable on handling AI related processes.

1. **SECURITY FEATURES ON CHIP**

Microprocessor security is critical in modern computing since processors are the foundation of all digital systems. As technology advances, the dangers and risks to these systems become increasingly complicated. Protecting the integrity and confidentiality of data handled by microprocessors has become a vital issue. Security is no longer only a software concern; it must be integrated into the hardware itself to which numerous microprocessor companies have long developed.

The history of security features embedded in microprocessors is rooted in the need to address hardware-level vulnerabilities that traditional software-based defenses could not mitigate during the development of the Intel 4004 processor. Early computing systems relied primarily on operating system–level access controls (user mode and kernel mode) and security application software, but flaws such as memory leaks and privilege escalation still posed a threat for computer security (Stallings, 2018). To counter these threats, companies introduced hardware-assisted security primitives, including hardware random number generators (RNGs), memory protection units (MPUs), and encryption of instruction sets, such as Intel’s AES-NI for accelerating encryption (Gueron, 2010). By the late 1990s and early 2000s, the notion of a hardware root of trust and isolated execution environments emerged, giving rise to technologies such as Intel Trusted Execution Technology (TXT) which acts similarly to today’s secure boot. It is an embedded hardware technology on intel microprocessors that provides mechanisms for protected execution of malicious instructions and software-based exploits (Intel Corporation, 2024).

Modern microprocessors now implement a wide range of embedded security features. Trusted Platform Module (TPM) 2.0 is a hardware-based security microprocessor feature which securely stores encryption keys, certificates, and platform measurements for identifying valid and licensed software and operating systems in order to deemed fit to operate (Trusted Computing Group, 2019). Similarly, Secure Boot also does the same function (UEFI Forum, 2019). These mechanisms are now embedded in modern microprocessors in order to prevent kernel-level or even hardware level exploits.

1. **INTEGRATION OF CONNECTIVITY ON MICROPROCESSORS AND CHIPS**

The integration of connectivity into microprocessors and microcontrollers has become a defining trend in modern computing. As devices evolve, connectivity allows them to communicate, share data, and interact with larger networks. This shift has enabled the rise of the Internet of Things (IoT), smart devices, and real-time communication systems across industries. By embedding connectivity directly into microprocessors, manufacturers reduce hardware complexity and power consumption which leads to the simplification of microcomputer developments and significant reduction of costs in formulating separate hardware for connectivity.

The history of connectivity in microprocessors and microcontrollers traces back to the mid-1990s, when embedded systems began transitioning from isolated controllers with not concept of connectivity in mind to networked devices. Early efforts included wired communication standards such as Ethernet, which provided links for industrial and enterprise systems (Wired, 1997). By the late 1990s, wireless technologies like Wi-Fi and Bluetooth emerged, marking the first steps toward low-power, short-range connectivity on microcomputers (GSMArena, 2016).

Today, many microcontrollers and microprocessors already come with built-in wireless features. Popular chips like Espressif’s ESP32 include Wi-Fi and Bluetooth, making them widely used in IoT projects (Espressif Systems, n.d.). Other companies such as NXP, also produce chips that support multiple standards like Wi-Fi and Bluetooth (NXP Semiconductors, 2022). Modern designs now focus on making connections more secure, reliable, and energy-efficient.

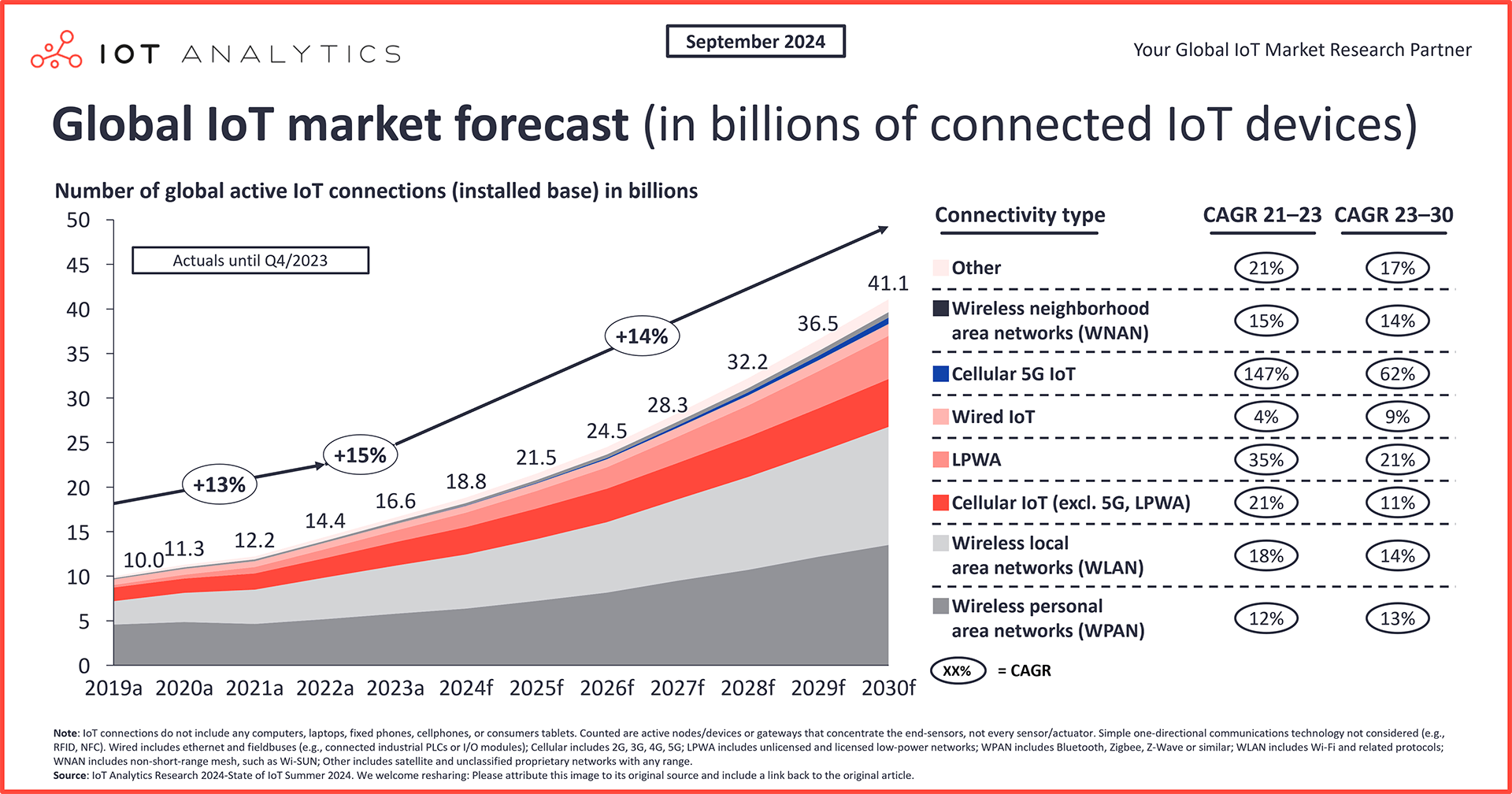


Figure 1.2: Global IoT Market Forecast (Sinha, 2023)

The following graph presents an upward trend of IoT devices utilized during the years 2019 onwards with an expected 14% increase in trend of IoT devices for the years consecutive to 2023. This goes to show that there would be a potential upward trend for more development of microprocessors as and microcomputers with integrated connectivity without the utilization of external hardware just for that purpose.

1. **QUANTUM COMPUTING**

Quantum computing uses the principles of quantum mechanics such as superposition and entanglement in order to process information in ways impossible for classical computers. Unlike traditional bits, “qubits” can hold multiple states at once, allowing faster solutions for complex problems in fields like cryptography, AI, and deep learning (TechRadar, 2025). Although the technology is still in it’s early stages, quantum computing is a realm of computer engineering that would soon come to light as more advances develop.

Quantum computing was first theorized in the 1980s by Richard Feynman and Yuri Manin. The two stipulated that classical systems (such as desktops) cannot outperform quantum systems. This paved the way for the formal definition of quantum computers. In the 1990s, **Shor’s algorithm** showed that quantum computers could factor large numbers exponentially faster. This presented one of the first theoretical results of the prowess of quantum computing. The advances in physical qubit implementations (e.g., superconducting qubits) paved the way for real prototypes. For context, Qubits, with respect to quantum computing, is a type of bit that has three states, 1, 0, and the state in between 1 and 0 (Schneider & Smalley, n.d.). A major milestone occurred in 2019, when Google demonstrated quantum supremacy by solving a problem in 200 seconds that would take supercomputers thousands of years (NIST, 2025).

In 2025, Microsoft introduced the Majorana 1 chip, which uses a new material called a “topoconductor” to create more reliable qubits. For context, Qubits are inherently fragile. Microsoft’s approach uses Majorana zero modes, which acts as foundations for the aforementioned qubits, making the qubit less likely to break down from noise or temperature changes (Koetsier, 2025). This methodology is called “topological protection” which greatly stabilizes the utilization of numerous qubits and reduce errors during vast computations and intensive data-handling.

A graph showing the growth of a company

AI-generated content may be incorrect.

Figure 1.3: Quantum Computing Forecasted Growth (Bobier et al., 2024)

Figure 1.3 presents the forecasted growth of investments towards quantum computing development and market in general. The bar graph shows an inherent trend for quantum computing investment from the years 2019-2024. Projected investment potentials for the industry are expected to be 25% for the proceeding years. This incentivizes companies for further research and development for quantum computing technology for microprocessors that would hopefully reach practical use and be sold commercially.

1. **NEUMORPHIC COMPUTING**

Neuromorphic computing is a new trend in microprocessor design that attempts to copy how the human brain works. Instead of processing data step by step like normal CPUs, these systems use brain-inspired structures to make decisions efficiently. This makes them useful for tasks like pattern recognition, sensory processing, and AI learning.

The concept of neuromorphic computing was first introduced in the 1980s by Carver Mead, who suggested building circuits that mimic biological neurons of a living creature (Mead, 1990). Over time, advances in semiconductor technology made it possible to design processors that use spikes and event-driven signals, similar to how the brain works.

Some of today’s leading neuromorphic processors include Intel’s Loihi chip, which uses “neural networks” to simulate brain-like communication, and IBM’s TrueNorth, which integrates over one million “neurons” on a single chip. These processors are designed to handle real-time learning and adaptive control (Davies et al., 2018). Neuromorphic computing is still in its early stages but shows strong potential for future AI models.

A graph of the market size

AI-generated content may be incorrect.

Figure 1.4: Neuromorphic Computing Market Projection (Precedence Research, 2025)

The following bar graph presents projection rates for Neumorphic Computing. 2024-2025 shows an increase in Nuemorphic computing. For the consecutive years, there is a projected upward trend up until 2034 for Nuemorphic computing investment. This stipulates that there would be yearly significant developments with regards to this specific microprocessor industry.

**References:**

* **AI World Society (AIWS). (2025, August 24). *Computer Scientist James Robert Slagle Developed SAINT*.**[**https://aiws.net/aiws-history-of-ai/the-history-of-ai/this-week-in-the-history-of-ai-at-aiws-net-computer-scientist-james-robert-slagle-developed-saint/**](https://aiws.net/aiws-history-of-ai/the-history-of-ai/this-week-in-the-history-of-ai-at-aiws-net-computer-scientist-james-robert-slagle-developed-saint/)
* **Bobier, J.-F., Langione, M., Naudet-Baulieu, C., Cui, Z., & Watanabe, E. (2024, July 18). *The long-term forecast for quantum computing still looks bright*. Boston Consulting Group.** [**https://www.bcg.com/publications/2024/long-term-forecast-for-quantum-computing-still-looks-bright**](https://www.bcg.com/publications/2024/long-term-forecast-for-quantum-computing-still-looks-bright)[**BCG+1**](https://www.bcg.com/publications/2024/long-term-forecast-for-quantum-computing-still-looks-bright?utm_source=chatgpt.com)
* **Espressif Systems. (n.d.). *ESP32*.**[**https://www.espressif.com/en/products/socs/esp32**](https://www.espressif.com/en/products/socs/esp32)
* **GSMArena. (2016, September 21). *Flashback: A quick look back at Wi-Fi’s history*.** [**https://m.gsmarena.com/flashback\_a\_quick\_look\_back\_at\_wifis\_history-news-57579.php**](https://m.gsmarena.com/flashback_a_quick_look_back_at_wifis_history-news-57579.php)
* **Intel Corporation. (2024, January 17). *Intel® Trusted Execution Technology (Intel® TXT) overview*.**
* **Khan, F. H., Pasha, M. A., & Masud, S. (2021). Advancements in Microprocessor Architecture for Ubiquitous AI-An Overview on History, Evolution, and Upcoming Challenges in AI Implementation. *Micromachines*, *12*(6), 665.** [**https://doi.org/10.3390/mi12060665**](https://doi.org/10.3390/mi12060665)
* **Koetsier, J. (2025, February 19). *Massive Microsoft quantum computer breakthrough uses new state of matter*. Forbes.** [**https://www.forbes.com/sites/johnkoetsier/2025/02/19/massive-microsoft-quantum-computer-breakthrough-uses-new-state-of-matter/**](https://www.forbes.com/sites/johnkoetsier/2025/02/19/massive-microsoft-quantum-computer-breakthrough-uses-new-state-of-matter/)
* **Lawrence Livermore National Library. (n.d.). *The Birth of Artificial Intelligence (AI) Research*. Science and Technology.**[**https://st.llnl.gov/news/look-back/birth-artificial-intelligence-ai-research**](https://st.llnl.gov/news/look-back/birth-artificial-intelligence-ai-research)
* **Mead, C. (1990). Neuromorphic electronic systems. *Proceedings of the IEEE, 78*(10), 1629–1636.** [**https://doi.org/10.1109/5.58356**](https://doi.org/10.1109/5.58356)
* **NIST. (2025, March 24). *Quantum computing explained*.** [**https://www.nist.gov/quantum-information-science/quantum-computing-explained**](https://www.nist.gov/quantum-information-science/quantum-computing-explained)
* **NXP Semiconductors. (2022, May 10). *The heart of Matter: The IW612 tri-radio solution.* NXP.** [**https://www.nxp.com/company/about-nxp/smarter-world-blog/BL-THE-HEART-OF-THE-MATTER**](https://www.nxp.com/company/about-nxp/smarter-world-blog/BL-THE-HEART-OF-THE-MATTER)
* **Precedence Research. (2025, May 16). *Neuromorphic Computing Market Size to Surpass USD 47.31B by 2034*.**[**https://www.precedenceresearch.com/neuromorphic-computing-market**](https://www.precedenceresearch.com/neuromorphic-computing-market)
* **Schneider, J., & Smalley, I. (n.d.). *What is a Qubit?* IBM .**[**https://www.ibm.com/think/topics/qubit**](https://www.ibm.com/think/topics/qubit)
* **Sinha, S. (2023, August 3). *State of IoT 2023: Number of connected IoT devices growing 16% to 16.7 billion globally*. IoT Analytics.**[**https://iot-analytics.com/number-connected-iot-devices/**](https://iot-analytics.com/number-connected-iot-devices/)
* **Stallings, W. (2018). *Computer Security: Principles and Practice* (4th ed.). Pearson.**
* **TechRadar. (2025, April 22). *Quantum computing explained: what it means for cybersecurity—and why it’s coming faster than you think*.** [**https://www.techradar.com/pro/quantum-computing-explained-what-it-means-for-cybersecurity-and-why-its-coming-faster-than-you-think**](https://www.techradar.com/pro/quantum-computing-explained-what-it-means-for-cybersecurity-and-why-its-coming-faster-than-you-think)
* **Trusted Computing Group. (2019). *TPM 2.0 Library Specification*.**
* **UEFI Forum. (2019). *UEFI Specification, Version 2.8*.**
* **Wired. (1997, April 21). *Intel’s tastes turn to networking.* Wired.** [**https://www.wired.com/1997/04/intels-tastes-turn-to-networking/**](https://www.wired.com/1997/04/intels-tastes-turn-to-networking/)