(EENG 5560) Research Project Report Template

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1. Reconfigurable Computing for IoT

• Fundamental theory/ concepts:

The Internet of Things, or IoT, is the collective term for the network of interconnected gadgets as well as the technology that enables communication between devices and the cloud.
An Internet of Things ecosystem is made up of web-enabled smart devices that gather, transmit, and act upon data they obtain from their surroundings using embedded systems including processors, sensors, and communication gear [1].
IoT has many potential uses, and its effects are already being seen in many different areas, including as manufacturing, transportation, healthcare, and agriculture. The Internet of Things (IoT) is expected to become more significant in influencing our world as the number of devices linked to the internet rises. Changing how we work, live, and relate to each other

• How reconfigurable computing is useful in that area:

Flexibility and Adaptability: Hardware can be dynamically modified to meet evolving requirements thanks to reconfigurable computing. Reconfigurability guarantees that the hardware may be adapted for various functionality in the Internet of Things, where devices may need to undertake a variety of activities or adapt to changing environmental circumstances.
Energy Efficiency: Field-Programmable Gate Arrays (FPGAs) and other reconfigurable computing devices can be dynamically modified to execute energy-efficient algorithms for certain Internet of Things jobs. This flexibility aids in reducing power usage, an important factor for Internet of Things devices that are frequently battery-operated.
Customization for Specific Applications: The Internet of Things has many uses, ranging from industrial automation to smart homes. Reconfigurable computing makes it possible to modify hardware to suit the unique requirements of various Internet of Things applications. This may lead to more effective and optimal solutions that are customized to meet the needs of a certain use case.
Resource Optimization: In the Internet of Things, resources like processing power, storage capacity, and bandwidth are frequently scarce. The efficient use of these resources is made possible by reconfigurable computing, which prevents overprovisioning by enabling hardware to be customized to the unique requirements of the application.
Security Enhancements : Reconfigurable computing has the potential to make Internet of Things devices more secure. Manufacturers can handle growing threats and vulnerabilities by implementing security updates or adjustments by permitting reconfiguration of the hardware.

• Company 1:

○ Achronix Semiconductor Corporation

Achronix Semiconductor Corporation is a fabless semiconductor company that provides premium FPGA-based data acceleration solutions for high-performance, compute-intensive, and real-time processing applications. Only Achronix offers licensed eFPGA IP solutions in addition to high-density, high-performance standalone FPGAs. Ready-to-use VectorPath® accelerator cards for AI, machine learning, networking, and data center applications substantially improve Achronix Speedster®7t FPGA and SpeedcoreTM eFPGA IP portfolios. The Achronix Tool Suite allows users to easily create bespoke apps and provides full support for all Achronix products.

- ### Motivation and Significance:

Hardware assurance benefits greatly from embedded Field-Programmable Gate Array Intellectual Property, or eFPGA IP. An Application-Specific Integrated Circuit (ASIC) that incorporates eFPGA technology allows chip designers to effectively address logic, memory, and Digital Signal Processing (DSP) needs. Traditional ASICs carry a number of supply-chain and life-cycle hazards, which are mitigated in part by this integration. The use of eFPGA is noteworthy because it enables in-field updates, hence mitigating potential future design concerns. The placement of both secure and non-secure intellectual properties is optimized by the tight integration between the ASIC and eFPGA IP, promoting a streamlined and cooperative process. Moreover, in comparison to discrete FPGA solutions, this method yields lower costs, less power consumption, and a smaller board footprint. Most importantly, using eFPGA improves security.[1]

- ### Key findings/contributions:

Modern security protections are built into Achronix SpeedcoreTM eFPGA IP to protect sensitive data while it's in use. The IP employs RSA public/private key authentication before starting to decode a configuration block, guaranteeing a safe and authenticated start. Strong protection and authentication are provided by the 256-bit AES-GCM encryption added to the configuration data. The system uses DPA countermeasures and rotating keys to thwart side-channel assaults. Secure key storage is also included, strengthened by physically unclonable functions that prevent efforts at overbuilding and cloning. To put it simply, Achronix SpeedcoreTM eFPGA IP puts advanced security measures first, offering a safe and reliable environment for electronic system configuration and operation.

eFPGAs enable vital intellectual property (IP) to change over time, adding a dynamic element to electronic systems. This flexibility becomes especially important when dealing with new security risks, like unanticipated side-channel attacks that weren't considered during the original design stage. Furthermore, the ability to modify the design after deployment turns into a useful feature that can accommodate any adjustments to the operational requirements that might occur once the hardware is placed in use. This adaptability is crucial for long product lifecycles of ten years or more because it makes it possible to add new features to satisfy changing customer needs and maintain the security and continued relevance of electronic systems over time.

• Company 2:

- ### QuickLogic Corporation:

QuickLogic possesses more than three decades of expertise in programmable logic devices, software, and intellectual property. It is the leading manufacturer of embedded FPGA solutions with ultra-low power, high performance, and low cost in the world. Developers may easily meet rapidly changing market requirements, support developing standards, and address many applications with a single mask set thanks to the company's ArcticProTM eFPGA technology. This eliminates the need for an expensive and time-consuming redesign and enables post-production customization of SoC designs.

- **Motivation and Significance:**

By utilizing embedded FPGA (eFPGA) technology, SoC designers and architects can quickly and easily achieve post-production design flexibility in SoCs. Additionally, Quick Logic's eFPGA IP can save power consumption and enhance overall system performance. QuickLogic provides a complete solution that comprises hardware acceleration blocks and hard intellectual property, and its FPGA development tools are 100% open source.

- **Key findings/contributions:**

The strategic focus on overcoming major obstacles and capitalizing on the distinct advantages provided by this technology drives QuickLogic Corporation's dedication to reconfigurable computing in the Internet of Things (IoT). The main driving force is the search for low-power solutions, which are essential for Internet of Things devices that run on limited power supplies. The flexibility and adaptability required to handle the dynamic nature of Internet of Things applications are provided by reconfigurable computing. With this versatility, QuickLogic hopes to customize hardware to meet a range of needs for different Internet of Things use cases. Reconfigurable computing helps the Internet of Things operate more efficiently by enabling real-time processing of sensor data at the edge, which lessens the need for centralized servers. The possibilities of IoT devices are further enhanced by the ability to expedite artificial intelligence tasks at the edge. QuickLogic places a strong focus on customization, which also includes cost-effective solution delivery, improved IoT device connectivity, and optimized communication interfaces. The technique developed by QuickLogic is significant because it has the potential to aid in the creation of effective, flexible, and affordable IoT solutions that cater to the changing demands of the IoT environment. It is advised to consult QuickLogic's official literature and recent announcements for the most updated insights.

- **References:**

1. https://www.achronix.com/sites/default/files/docs/Achronix_Maximize_Hardware_Assurance_Using_Embedded_FPGAs_Infographic.pdf
2. https://www.quicklogic.com/products/efpga/arcticpro/

2. Reconfigurable Computing for Bioinformatics

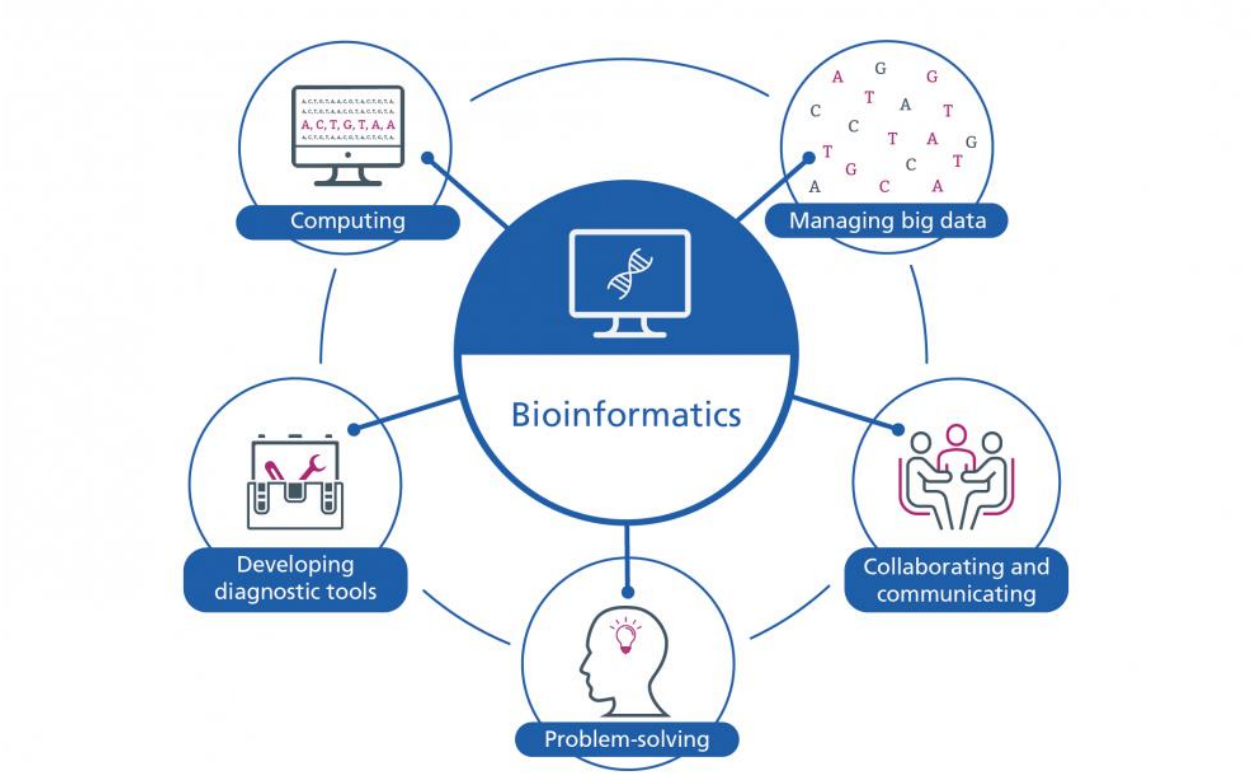
- **Fundamental theory/ concepts:**

As it relates to genetics and genomics, bioinformatics is a scientific sub discipline that uses computer technology to gather, store, analyse, and share biological data and information, including sequences of amino acids and DNA and annotations about those sequences. To improve our understanding of health and disease and, in some situations, as part of medical care, scientists and physicians employ databases that organize and index biological information. In order to improve our comprehension and interpretation of biological data, the relatively new and developing field of bioinformatics integrates knowledge and tools from biology and computer

science. Given that genomics can produce enormous amounts of data, bioinformatics is very helpful in this subject. In order to diagnose a patient with a rare disease, follow and monitor infectious organisms as they spread throughout a population, or determine the most effective course of treatment for a cancer patient, bioinformatics is employed to assist give meaning to the data.

- **How reconfigurable computing is useful in that area:**

Reconfigurable architectures for bioinformatics have seen a lot of research and intriguing outcomes in recent years. Reconfigurable technology is highly useful because of the volume and variety of individually tailored versions for these applications.
Computer scientists handle computational biology challenges like phylogenetics and DNA string matching in the field of bioinformatics. Reconfigurable technology has been used in the past several years to implement complex bioinformatics algorithms, including the BLAST algorithm for DNA string matching, T-COFFEE and MAFFT for DNA assembly, Zuker's algorithm and Predator for genetic data secondary structure prediction, and the RAxML method for phylogenetic tree likelihood estimation. When compared to competing technology like general-purpose CPUs, the outcomes are rather remarkable.
Comparing reconfigurable computing to general-purpose processors, the main benefit is that virtually infinite parallelism, including arbitrarily wide datapaths, can be discovered and exploited at the cost of a lOx reduction in clock speed (a distinct advantage vs. the 32- or 64-bit choices in general-purpose computers). The BLAST method may be used with strings of 1,000–10,000 elements drawn from a 4- or 20-letter alphabet to demonstrate this benefit. Once these are reduced to the so-called w-mers, which are 3–100 characters wide, they are compared in a streaming method against a multi-Gbyte database. Not only are these datapaths readily implementable in FPGAs, but they also provide the designer with completely adjustable processing element granularity.
Direct connections also enable internal communication between processor parts, which is a clear benefit over general-purpose computers. In comparison to those technologies, the resulting speedups are in the region of lOx to 1,000x. In contrast to VLSI, where the datapath is also subject to arbitrary choices, the primary trade-off is between speed and flexibility. When compared to FPGAs, the VLSI technique is usually lOx quicker; however, it does not have the option to modify the system's dimensioning. With FPGAs, an algorithm can have implementations "tuned" to the specifics of the selected variant (e.g., BLASTn, BLASTp, etc.). Finally, taking into account that reconfigurable computing typically achieves a 30x speedup over general-purpose computing at roughly the same power consumption, the total energy utilized is also 30x lower.



- **Company 1:**
    - **Edico Genome(now part of illumina):**

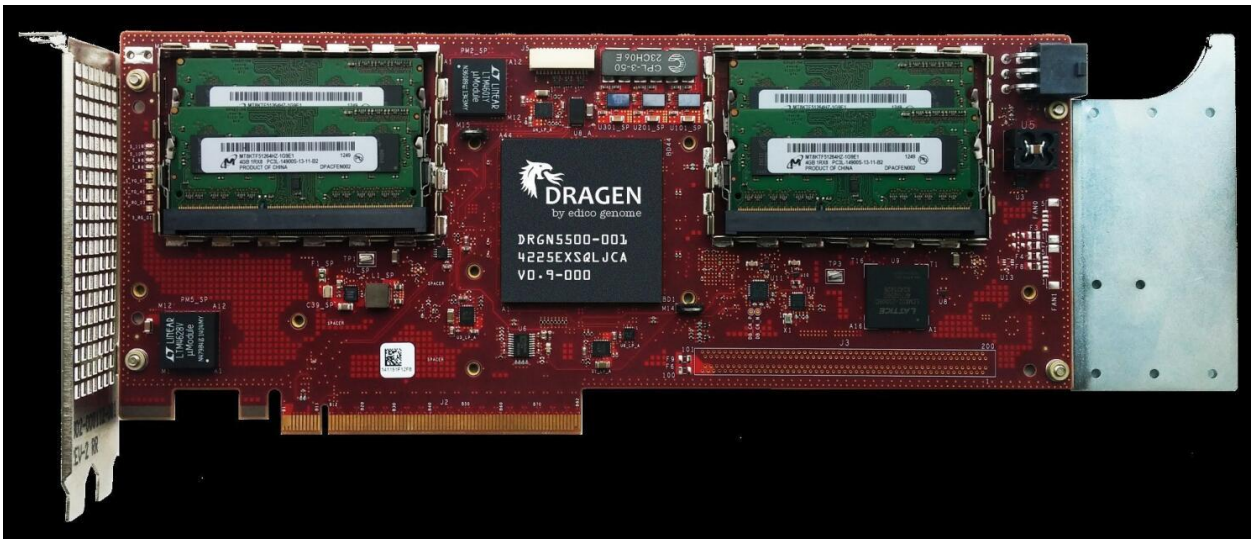
Illumina acquires Edico Genome to accelerate Genomic data analysis[1].

- **Motivation and Significance:**

The revolutionary influence of Edico Genome's DRAGEN Bio-IT Platform on genomics and bioinformatics highlights its relevance. DRAGEN, designed for high-speed genomic data analysis, enables large-scale datasets to be processed quickly, meeting the urgent requirement for prompt results in clinical diagnosis and research. Because of its resource-efficient computational technique, genomic analysis is now more widely available to a wider range of academics and organizations. Because of the platform's scalability, it can easily accommodate increasingly complex datasets and adjust to the changing landscape of genomics research. DRAGEN is widely used because of its adaptability in a range of genomic applications, from clinical diagnostics to research. Specifically, the focus on accuracy and precision improves the dependability of the results of genomic analyses, supporting the caliber of research products and medical interpretations. DRAGEN is a user-friendly technology that integrates seamlessly into workflows that are already in place, making it easier for established practices to use. The platform is a valuable resource in the genomics community because of its contributions to the fields of personalized medicine, disease knowledge, and targeted therapy development.

- **Key findings/contributions:**

By creating the DRAGEN (Dynamic Read Analysis for Genomics) platform, Edico Genome made a substantial contribution to the field of bioinformatics. A bioinformatics processor called DRAGEN uses FPGAs to speed up the analysis of genomic data. Next-generation sequencing technologies are producing ever-larger volumes of DNA sequencing data, which the platform is built to handle. The fast and effective processing of genomic data, including variant calling, alignment, and annotation, is made possible by Edico Genome's FPGA-based methodology. Significantly shorter analysis times and improved scalability are achieved by the use of FPGAs, which enable parallel processing and algorithm customisation. The efficiency and speed of genetic data interpretation and analysis were impacted by Illumina's acquisition of Edico Genome, which further reinforced the integration of FPGA-accelerated technologies into genomics processes.



- **Company 2:**

- **Convey Computer:**

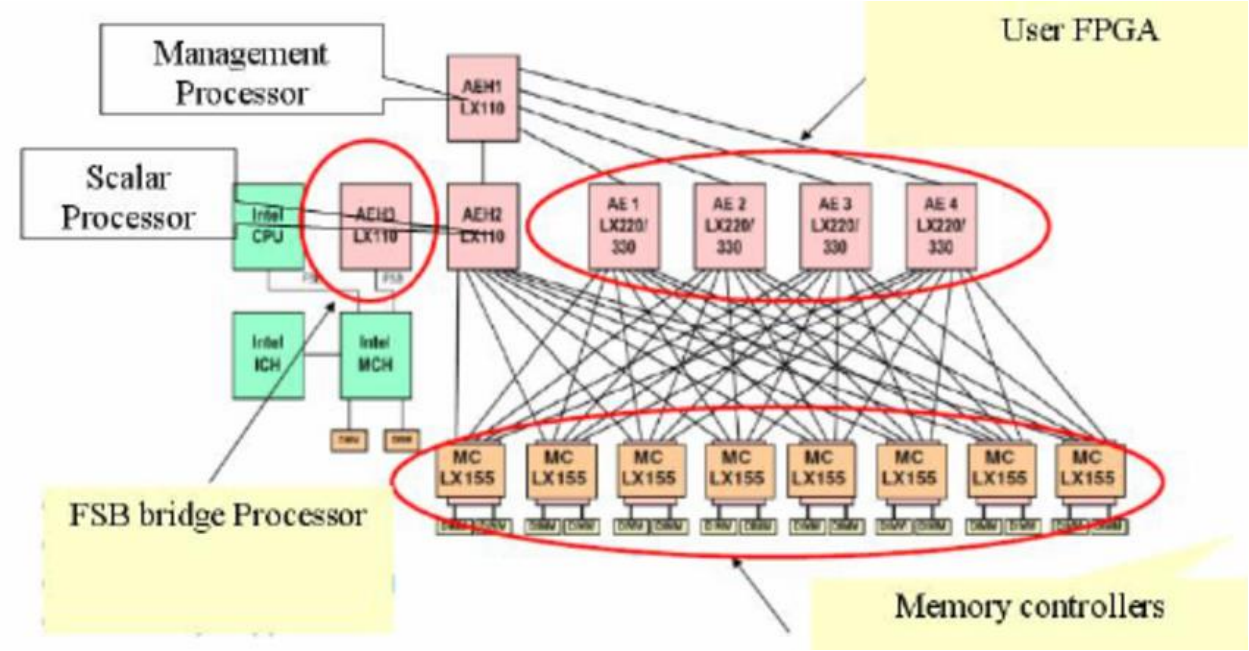
Convey Computer, a hardware manufacturer that specializes in hybrid-core systems that combine multicore processors and FPGAs, announced back in May that the Virginia Bioinformatics Institute at Virginia Tech had selected its systems for text mining and policy informatics applications in addition to the 1,000 Genomes project. Convey's hybrid-FPGA solutions have also been adopted by the University of South Carolina's Heterogeneous and Reconfigurable Computing Group, which is investigating ways to accelerate phylogenetic inference techniques. Convey unveiled its HC-1ex hybrid rack system in November, claiming that it can operate an optimized Smith-Waterman version at 401 times the speed of conventional x86 CPUs.

- **Motivation and Significance:**

Power/density, which is brought on by rising clock frequencies and system complexity, has become the design limiting factor in recent years, resulting in a deceleration in single-core performance. It is

practically hard to overcome the heat and power brick wall generated by the laws of physics with conventional CPU and semiconductor architectures.

Businesses have resorted to heterogeneous computer architectures, which use semiconductor gates in more effective combinations, in an effort to get beyond the laws of physics. In particular, application-specific tasks are carried out directly in hardware by computing components like field programmable gate arrays (FPGAs) and general-purpose graphics processing units (GPGPUs). The end result is a combination that both significantly boosts raw performance and efficiency (measured in performance-per-watt).[4]



- **Key findings/contributions:**

In order to speed up bioinformatics applications, Convey Computer led the way in developing hybrid-core computing platforms, which combine conventional processors with FPGAs. The systems of the company are engineered to optimize techniques that are frequently employed in genomics research, including simulations of molecular dynamics and sequence alignment. Convey's solutions demonstrated significant gains in computational efficiency for bioinformatics operations by utilizing the parallel processing capabilities of FPGAs. By addressing the increasing need for high-throughput genomic data analysis, these advances helped scientists better understand complex biological systems. Convey's novel approach to hybrid-core computing brought bioinformatics research to a new level by highlighting the significance of hardware acceleration for computationally demanding activities like as genomics.

- **References:**

3. https://www.illumina.com/company/news-center/press-releases/2018/2349147.html
4. https://wikis.ece.iastate.edu/cpre584/images/2/2c/Convey_HC-2_Architectual_Overview.pdf

3. Reconfigurable Computing for Video processing

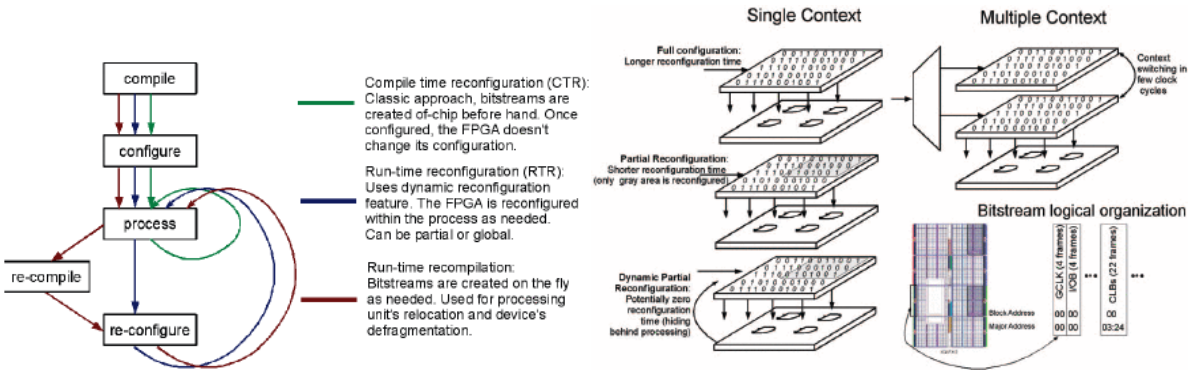
• Fundamental theory/ concepts:

The technology that makes it possible to manipulate and improve video signals—improving their clarity, colour, and overall quality is known as video processing. It's the enchantment that produces breath taking film scenes and clear video chats. It's crucial in the modern digital environment, from compression to format conversion. To alter the visuals and sound recorded in video files, video processing employs hardware, software, and combinations of the two. The peripheral devices and processing software include extensive algorithms that let the user do editing tasks with different filters. Editing can be done in larger batches or frame by frame to achieve the desired effects.

• How reconfigurable computing is useful in that area:

The initial devices employed for this function were capable of simultaneously storing many configuration pictures and switching between them in a short amount of clock cycles. These gadgets were referred to as multi context devices. Keeping many configuration contexts became unfeasible as devices became denser. As seen in Figure 1, later devices are single-context, which means that only one configuration picture is stored at a time. The time it takes to load a new configuration each time a change or reconfiguration is necessary limits single-context devices. In the literature, this period of time is known as reconfiguration time overhead. By running computations on one device while reconfiguring the others as necessary, reconfigurable systems leveraged numerous devices to partially disguise the reconfiguration time delay.

Reconfiguration is not frequently used in this schema; instead, it is more of a whole application update than a modification to the program itself. Two novel properties of modern devices have made it possible for a wide range of applications to make heavier use of reconfiguration. Run-time partial reconfiguration comes first. By enabling the upload of partial configurations, or fewer bitstreams, partial reconfiguration lowers the overhead associated with reconfiguration time. Runtime is the capacity to carry out partial reconfiguration while maintaining the functionality of the device's unaltered components. Access to the configuration memory from within the device's fabric is the second feature. Thus, a gadget has the ability to change its configuration. The paradigm of reconfigurable computing has advanced in the direction of system-on-a-chip (SoC) self-reconfigurable computing systems thanks to these two characteristics.



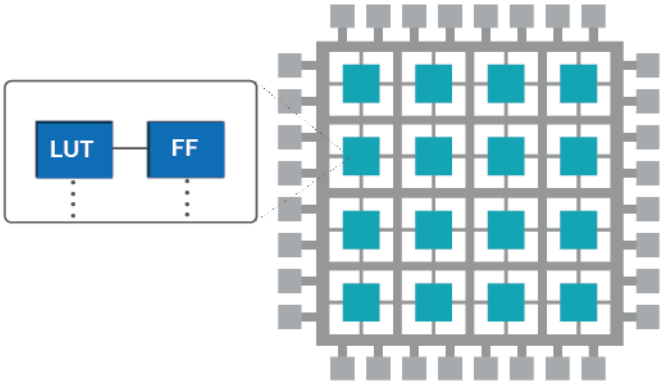
- **Company 1:**

  - **Quick Logic Corporation:**

QuickLogic has over 30 years of experience with programmable logic devices, software, and intellectual property. It is the world's top creator of ultra-low power, high performance, low cost embedded FPGA solutions. Thanks to the company's ArcticProTM eFPGA technology, developers can easily address rapidly evolving market requirements, support emerging standards, and address multiple applications with a single mask set. This allows SoC designs to be customized post-production without requiring an expensive and time-consuming redesign.[5]

  - **Motivation and Significance:**

SoC designers and architects can easily and quickly gain post-production design flexibility in SoCs with the use of embedded FPGA (eFPGA) technology. Quick Logic's eFPGA IP can also reduce power consumption and improve system performance overall. With 100% open source development FPGA tools, QuickLogic offers a comprehensive solution that includes hardware acceleration blocks and hard intellectual property.



- **Key findings/contributions:**

The ability to offload important functions to the eFPGA and increase system performance or decrease system power consumption is a major advantage of integrating the eFPGA into a SoC. In addition, QuickLogic offers an API for software developers and ASIC and FPGA-based function blocks that can be easily integrated with the eFPGA array through intimate coupling. FFTs and FIR filters are a couple of examples of this. Reconfigurable computer technologies from QuickLogic Corporation, in particular their embedded FPGA (eFPGA) technology, have a wide range of applications in the video processing industry.

Customizable video processing algorithms can be implemented on the eFPGA, giving designers the ability to create unique solutions for tasks like special effects, real-time modifications, and video enhancement. Because of its programmable nature, it enables dynamic adaptability in video processing, enabling instantaneous parameter alterations in response to shifting environmental factors or video material

. QuickLogic's eFPGA, which is seamlessly incorporated into video processing chains, improves the pipeline's overall flexibility and configurability, enabling effective video codec implementations and parallel processing for computationally demanding workloads. Interestingly, QuickLogic guarantees energy-efficient operations in video processing applications by emphasizing ultra-low-power solutions. video processing solutions that are flexible and effective in handling particular needs and jobs that are customary in the business. It is best to consult QuickLogic's official announcements and documentation for the most up-to-date and comprehensive information.

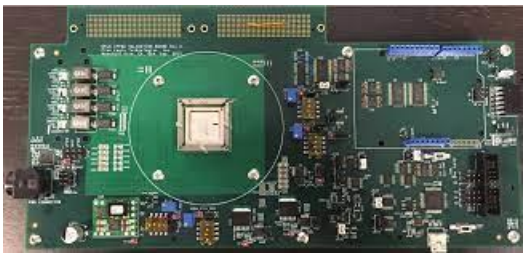
Company 2:

- **Flex Logix Technologies :**

With more than 20 operational chips and numerous more in design, Flex Logix has been providing eFPGA hardware and software solutions to dozens of customers for years.[6]

- **Motivation and Significance:**

Having become a major force in reconfigurable computing, Flex Logix Technologies specializes in providing cutting-edge eFPGA (embedded Field-Programmable Gate Array) IP solutions that are easily included into System-on-Chips (SoCs). The company's noteworthy accomplishments are centered around offering hardware acceleration that can be customized for a wide variety of applications, with a focus on video processing. By directly integrating reconfigurable logic into SoCs, Flex Logix's eFPGA IP enables designers to create customized hardware solutions that improve the efficiency of computationally demanding activities related to visual applications, such as image processing algorithms and video codecs.



- **Key findings/contributions:**

Flex Logix has made significant contributions, one of which is its focus on improving edge computing capabilities. The company responds to the growing need for efficient and localized data processing by incorporating eFPGA IP into SoCs for edge video processing. This is especially useful for applications like smart cameras, industrial automation, and surveillance since it reduces latency and increases responsiveness in video analytics. The technology of Flex Logix is built to handle the expanding convergence of artificial intelligence (AI) and reconfigurable computing. Optimization of video processing tasks involving AI algorithms, such as object detection, picture recognition, and content analysis, is made possible by the integration of eFPGA IP with AI acceleration within SoCs.

Flex Logix's collaborative efforts have established the company as a major player in the advancement of adaptable, high-performing solutions within the rapidly changing fields of edge computing and video processing. Additionally, Flex Logix's eFPGA IP is a useful tool for designers in the development stage since it allows for quick prototyping and testing. Because of its adaptability, video processing applications can experiment with various configurations and algorithms, which speeds up the design process and guarantees that the finished products will satisfy demanding performance standards. Flex Logix Technologies is in the forefront of reconfigurable computing in the video processing and edge AI space, responding to the growing demand for effective and customized video processing solutions.

- **References:**

5. https://www.quicklogic.com/products/efpga/arcticpro/
6. https://flex-logix.com/eflx-efpga/

4. Reconfigurable Computing for Audio processing

- **Fundamental theory/ concepts:**

The transformative skill of altering sound waves to improve clarity, modify tone, and provide auditory experiences is known as audio processing. It's the magic that creates the enthralling symphonies out of the unadulterated noise that powers your favorite movies, podcasts, and music.
To distinguish audio processing carried out by machines from that carried out by the biological auditory system, audio processing is frequently referred to as audio signal processing. Since the early days of radio broadcasting in the 1920s, audio signals have been mechanically processed.

The most common uses of audio processing are for pre-transmission signal enhancement or cleaning.

- **How reconfigurable computing is useful in that area:**

The audio processing industry benefits greatly from reconfigurable computing, especially when it comes to Field-Programmable Gate Arrays (FPGAs), which are redefining how sound is handled and manipulated. The capacity to use programmable signal processing algorithms is one of its main advantages since it enables designers to create custom solutions for certain audio processing jobs like noise reduction, equalization, and filtering. This flexibility is especially important given the wide range of audio applications, where several algorithms might be needed depending on the individual qualities of audio inputs.

Reconfigurable computing, made possible by FPGAs, has real-time processing capabilities that are essential for applications requiring low latency responses, such as interactive audio experiences, audio effects, and live sound processing. FPGAs provide a flexible solution for a range of audio processing applications since they are excellent at implementing audio codecs and guaranteeing high-quality compression and decompression of audio data with little latency. Furthermore, reconfigurable computing's adaptiveness helps to meet a range of audio processing requirements. FPGAs are appropriate for applications such as adaptive filtering and speech recognition because they can dynamically modify processing parameters and algorithms in response to variations in audio inputs.

Power consumption efficiency is an important factor to take into account, particularly for audio equipment that runs on batteries. Because FPGAs can be optimized for low-power operation through reconfigurable computing, audio processing activities can be carried out with low energy consumption and great processing efficiency. Moreover, FPGAs may execute many audio processing tasks simultaneously because to their intrinsic capability for parallel processing. This makes them appropriate for applications where concurrency is crucial, such as multichannel audio processing and spatial audio rendering. Real-time synthesis and dynamic audio effects are made possible in large part by reconfigurable computing.

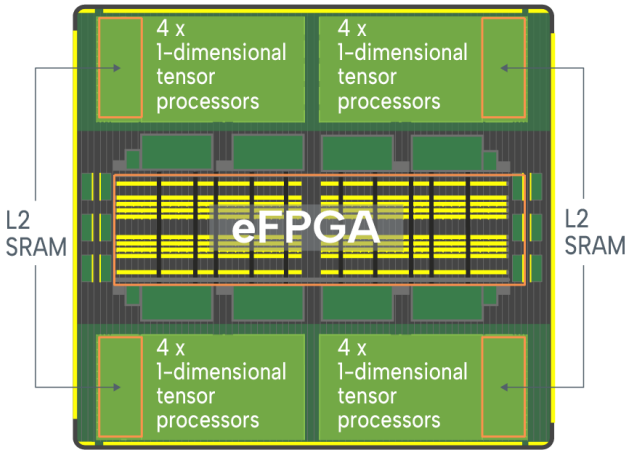
FPGAs can be programmed to do complex audio effects frequently used in audio engineering and music production, replicate a variety of instrument sounds, and construct advanced audio synthesis techniques. FPGAs provide an adaptable and configurable framework for audio processing development and prototype that extends beyond the application phase. Because of this flexibility, researchers and engineers can quickly iterate on their designs before finalizing the hardware by experimenting with multiple algorithms and processing approaches. Fundamentally, reconfigurable computing—which is best represented by FPGAs—gives the audio processing field unmatched flexibility, adaptability, and real-time capabilities, hence advancing audio technology in a variety of applications.

- **Company 1:**
  - **Flex Logix Technologies:**

For years, Flex Logix has been offering eFPGA hardware and software solutions to dozens of customers. The company currently has more than 20 operational chips and many more under design.

  - **Motivation and Significance:**

The embedded FPGA (eFPGA) technology developed by Flex Logix Technologies has great potential for audio processing applications. The installation of flexible and adjustable audio processing algorithms is made possible by this eFPGA, giving designers the ability to customize solutions for particular needs including equalization, filtering, and special effects. Low-latency audio processing is one of its main advantages; this is essential for real-time applications like interactive systems and live audio processing. Because eFPGAs are programmable, they may dynamically change processing settings in real time to adapt to changing user preferences or audio situations. Flex Logix's eFPGA improves overall flexibility and configurability when integrated into audio processing chains. This allows for the efficient implementation of audio codecs and adaptive filtering for noise reduction.
Flex Logix's eFPGA has a notable capability for low power consumption, which makes it appropriate for battery-powered devices and situations where energy efficiency is crucial. With the help of this technology, designers may efficiently and adaptably construct tailored solutions for particular audio processing tasks, meeting specific criteria. It is advised to review Flex Logix's official literature and case studies for the most recent and comprehensive information.



  - **Key findings/contributions:**

Flex Logix Technologies' cutting-edge eFPGA (embedded Field-Programmable Gate Array) IP solutions have significantly advanced the field of reconfigurable computing, especially in the audio processing domain. Through the direct integration of reconfigurable logic into SoCs (System-on-Chips), the company's eFPGA technology empowers designers and provides

unmatched customisation for audio processing applications. One noteworthy accomplishment is in real-time audio processing, where Flex Logix's eFPGA systems are excellent at providing low-latency responses that are necessary for dynamic audio effects, interactive audio experiences, and live sound processing. Flex Logix's improvement of eFPGA IP for energy-efficient audio processing, meeting the needs of battery-powered devices, is clear evidence of the company's dedication to providing low-power solutions.
The smooth incorporation of eFPGA into System-on-a-Chip (SoC) improves the effectiveness of audio algorithms, reducing the requirement for external components and increasing system performance. Multiple audio operations can be executed simultaneously thanks to Flex Logix's FPGAs' built-in support for parallel processing. This is an essential feature for multichannel processing and spatial audio rendering. Additionally, engineers and researchers can experiment with different algorithms and methodologies using Flex Logix's eFPGA IP, which promotes quick iteration and refinement. This makes Flex Logix's eFPGA IP a versatile and powerful tool for audio processing prototype and development. It is advised to consult Flex Logix Technologies' official communications, press releases, and technical publications for the most up-to-date and accurate information regarding their ongoing contributions.

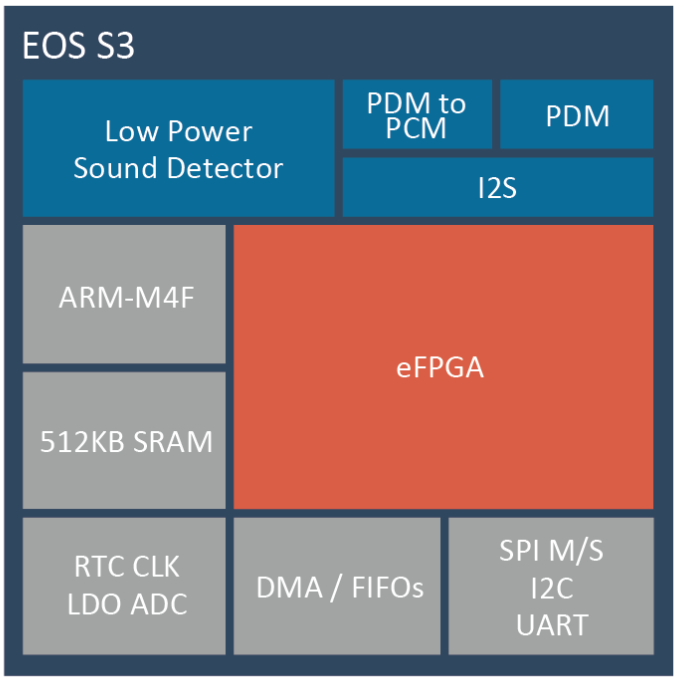
- # Company 2:

  - ## Quick Logic Corporation:

QuickLogic's products are unique in the audio processing industry because they offer programmable logic, which enables designers to apply proprietary signal processing algorithms. This flexibility is especially useful for tailoring audio codecs, filtering, and other signal processing operations to the unique needs of various applications. Especially, QuickLogic's eFPGA technology is flexible enough to meet the needs of edge AI and IoT devices, allowing for on-device modification and audio algorithm acceleration without a significant dependency on centralized servers.

  - ## Motivation and Significance:

Embedded FPGA (eFPGA) technology allows SoC designers and architects to quickly and easily achieve post-production design flexibility in SoCs. Additionally, Quick Logic's eFPGA IP can save power consumption and enhance overall system performance. QuickLogic provides a complete solution that comprises hardware acceleration blocks and hard intellectual property, and its FPGA development tools are 100% open source.



- **Key findings/contributions:**

Integrating low-power microcontrollers with QuickLogic's eFPGA technologies enhances system design efficiency. This integration makes it possible for the microcontroller and reconfigurable logic to work together seamlessly in audio processing applications, allowing for efficient and customized audio processing capabilities that adhere to power budget constraints. QuickLogic has made significant contributions to the wearable and Internet of Things (IoT) arena. Its eFPGA technology has improved the audio features of wearables and smart IoT-connected audio systems. The business has also produced advancements in energy-efficient voice and audio processing, which has helped applications like voice recognition in areas with limited resources. The continuous development of ultra-low-power, configurable eFPGA technology by QuickLogic Corporation highlights the company's contribution to the advancement of reconfigurable computing, especially in the area of highly flexible and energy-efficient audio processing solutions.

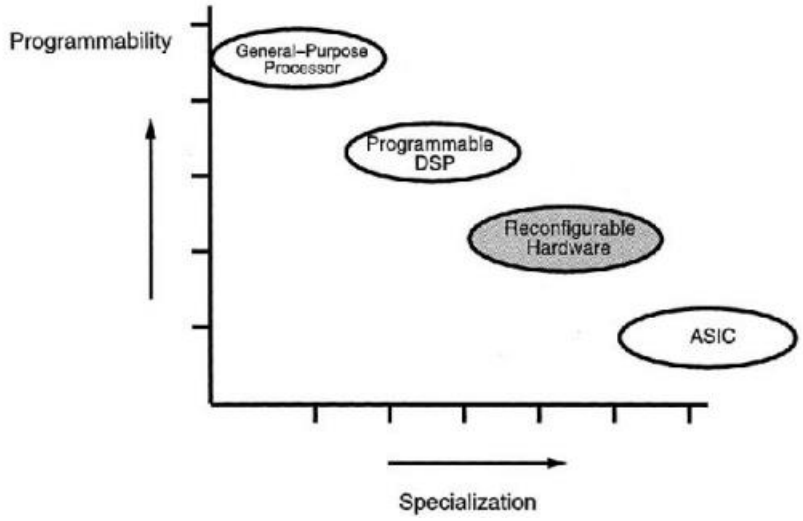
- **References:**

7. https://flex-logix.com/eflx-efpga/
8. https://www.quicklogic.com/products/efpga/arcticpro/

5. Reconfigurable Computing for Digital Signal Processing

- **Fundamental theory/ concepts:**

The process of evaluating and adjusting a signal to maximize or enhance its effectiveness or performance is known as digital signal processing, or DSP. To create a signal that is better than the original, it entails using a variety of computational and mathematical methods to analog and digital signals.
A specific computing method called digital signal processing (DSP) is used to examine, modify, and convert digital signals that are represented as discrete numerical sequences. Analog-to-digital conversion, or ADC, is the process of converting continuous analog signals into discrete form so that algorithms may be processed effectively. DSP is essential to many different fields because it can perform a wide range of functions, including modulation, convolution, filtering, and Fourier analysis. Applications include everything from processing photos and boosting audio quality to controlling dynamic systems in control engineering and advancing communication networks. DSP is implemented on platforms such as Field-Programmable Gate Arrays (FPGAs) and Digital Signal Processors (DSPs), offering an advanced toolkit for signal analysis and manipulation in several disciplines.



- **How reconfigurable computing is useful in that area:**

Over the past ten years, the application domain of digital signal processing has been greatly broadened by consistent advancements in VLSI technology and design tools. For many DSP applications, programmable digital signal processors (PDSPs) and application-specific integrated circuits (ASICs) are still the preferred implementation techniques; nevertheless, more and more novel system implementations based on reconfigurable computing are being explored. These adaptable platforms are rapidly developing as programmable devices' logic capacity increases in line with Moore's Law and more sophisticated automated design methods become accessible.

These platforms combine the functional efficiency of hardware with the programmability of software. With the emergence of the first reconfigurable technologies, new research and industry initiatives have been launched to enable improved run-time performance, cost reduction, and power optimization.
Reconfigurable computers provide a middle ground between software-programmable substrates' flexibility and hardware's fixed-functionality performance advantages. These systems differ from application-specific integrated circuits (ASICs) in that they can implement customized circuitry directly in hardware. Reconfigurable computers also have functional resources that can be readily changed following field deployment in response to shifting operational factors and datasets, much like programmable processors. Up until now, the majority of reconfigurable computers have used field programmable gate arrays (FPGAs) as their primary processing element. The large amounts of logic and register resources available on these bitprogrammable computing devices can be readily modified to accommodate the fine-grained parallelism required by many pipelined DSP applications. Each programmable device can integrate significant logic functionality because contemporary logic capacities surpass one million gates per device. Figure 1 DSP implementation spectrum is acceptable for certain classes of implementation. FPGAs are but one example of a variety of reconfigurable computer building pieces that can be used. Several reconfigurable options are now being studied in research and industry settings.

- # Company 1:
  - ## Analog Devices:

Digital signal processing, or DSP, is essential to many different fields and uses. To assist us in meeting our design objectives, they provide a range of digital signal processing solutions for applications such as automotive, portable, motor/power control, security, test and measurement, and more. Scalable low-latency audio performance is offered by their processor portfolio, which includes multi-channel IIR/FIR/FFT accelerators and huge on-chip SRAM with a variety of choices, including on-chip ASRCs, to enable real-time audio processing. TDM/I2S, Ethernet, MLB, CAN, SPI, I2C, UART, and numerous more system interfaces make them suitable for a broad range of embedded applications.[9]

  - ## Motivation and Significance:

Analog Devices Code- and pin-compatible DSPs with a maximum frequency of 160 MHz and a minimum power consumption of 184 microamps are the ADSP-21xx processors. Voice-band modems, speech processing, and real-time control applications are all well suited for the ADSP-21xx series of chips.

  - ## Key findings/contributions:

SigmaDSP Audio Processors:

For use in portable and automotive audio devices, SigmaDSP® processors are completely programmable, single-chip audio DSPs that are easily configured using the SigmaStudioTM graphical development tool. Sample rate converters, A/D converters, D/A converters, and output amplifiers are all built into SigmaDSP processors.

SigmaDSP Processors for TV:

For use in portable and automotive audio devices, SigmaDSP® processors are completely programmable, single-chip audio DSPs that are easily configured using the SigmaStudioTM graphical development tool. Sample rate converters, A/D converters, D/A converters, and output amplifiers are all built into SigmaDSP processors.

Company 2:

○ Intel Corporation (Altera):

A major turning point in the field of reconfigurable computing was reached with Intel Corporation's acquisition of Altera, especially in relation to Field-Programmable Gate Arrays (FPGAs). Before the acquisition, Altera was well-known for its adaptable solutions and had made a name for itself in the FPGA industry. The FPGA technology, which is currently a part of Intel, has made a significant contribution to high-performance computing by enabling users to modify digital circuits to meet certain requirements. [10]

○ Motivation and Significance:

With their integration with Intel's environment, Altera's FPGAs have been essential in the field of digital signal processing (DSP). Developers may now rapidly execute sophisticated DSP algorithms, parallel processing jobs, and real-time signal manipulations with low latency thanks to these FPGAs' programmable hardware acceleration.An coordinated strategy for heterogeneous computing has been achieved through the amalgamation of Altera's FPGA technology with Intel's processors and additional components. Tasks can be delegated to the FPGA for specialized handling in DSP applications, improving performance and enabling optimum parallel processing. Furthermore, the deliberate use of FPGAs as workload accelerators in data centers, including data analytics, machine learning, and signal processing applications, highlights their flexibility and versatility.

○ Key findings/contributions:

Now owned by Intel, Altera's FPGA technology is still essential in certain areas like networking and 5G. Communication systems have advanced thanks to the use of FPGAs in baseband processing, networking protocols, and data packet modification. The fact that FPGA architectures, tools, and solutions are always being improved shows how committed Altera and Intel are to research and development. This pledge demonstrates their commitment to innovation in reconfigurable computing and guarantees that FPGAs will continue to lead the way in technological developments in the domains of digital signal processing and related applications. To get the most up-to-date and comprehensive understanding of Intel's contributions in this field

• References:

9. https://www.analog.com/en/product-category/processors-dsp.html
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6. Reconfigurable Computing for AI/ML

- ## Fundamental theory/ concepts:

Machine learning is one artificial intelligence. artificial intelligence will learn gradually and develop overtime. It also learns from the tasks from matrix multiplication. They are also closely related to each other and formed using algorithm and models. Both of them help to the machine to learn and adopt the new situation.

- ## How reconfigurable computing is useful in that area:

Reconfigurable computing helps the machine to learn the algorithm by specific tasks like matrix multiplication and natural network interfaces

- ## Company 1:
  - ### Hewlett-Packard Enterprises:
  - ### Motivation and Significance:

They want develop the system which fit to today's technology.

  - ### Key findings/contributions:

BENZ want to develop their car as autonomous. They want the customer's to let go of the steering wheel while driving which help with the accident-free driving. they also need to collect all the data from the sensors and cameras.

It also has to deal with lot of small files which make the slow in the performance. Only HPE Ezmeral Data Fabric to offer a solution to this problem. This is developed by HPE proliant DL380 and HPE 4530 and HPE 4510.

Some of the features of HPE apollo 4530 are memory has maximum of 4 TB, it also networks with HPE slingshot, it also supports the NVIDIA, AMD and other manufacturing companies.

- ## Company 2:
  - ### Intel:
  - ### Motivation and Significance:

They wanted to create a system which optimize AI.

  - ### Key findings/contributions:

Intel Stratix 10 NX FPGA is a new AI optimized block called AI tensor block. It also has a ability to matrix-matrix or vector-matrix multiplication which is capable to work efficiently for both small and large matrix sizes.

Some of the features are two times the clock frequency, it reduces the size by consolidating the multiple devices into single device and by this the power usage can be reduced by 70% and it also boost the performances.

Some of the applications are Data Centre Acceleration, Cognitive Computing, Wireline and Enabling New Network Infrastructure.

- **References:**

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12. https://www.intel.com/content/www/us/en/products/details/fpga/stratix/10/item.html

7. Reconfigurable Computing for Data Analytics

Fundamental theory/ concepts:

Data analytics is analysis of the raw data and help us to make some useful conclusions. In this process there are lots of algorithms and techniques that works on the raw data instead of human. it is required to collect, classify and analysis that come across statistics, computer science and machine learning.

How reconfigurable computing is useful in that area:

Reconfigurable computing fills between the normal purpose and specific use. It also an ability to match for different applications, improving performance and power consumption.

Company 1:

- **Amazon Web Services (AWS):**
- **Motivation and Significance:**

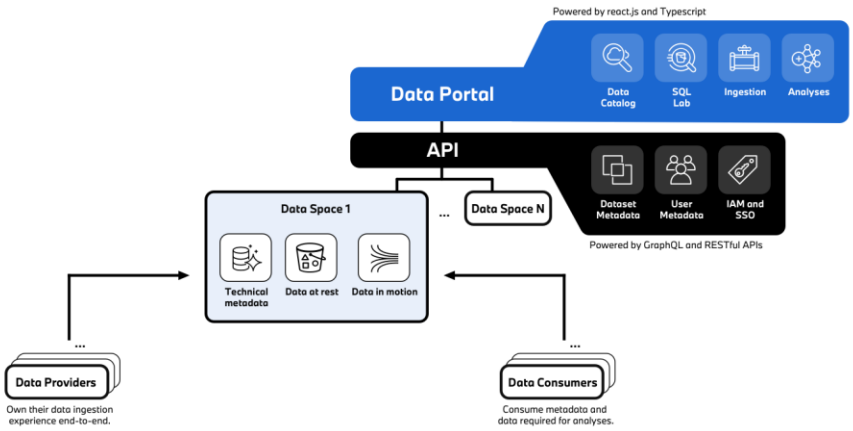
The main idea behind this is to provide services for the raw data to discover prepare and move the data from different sources and to analysis it.

- **Key findings/contributions:**

In this project AWS worked with BMW. Where it took about 10 TB data from the vehicles each day. They did this to know the real time data from the vehicle and also from the customer. As competition increases BMW want to stay ahead all of them so they digital transformed the data into predictable analytics.

With this data they came forward improving the efficiency and effectiveness. They also developed a solution that supports the data and customer's demand. The company has stored all its data in the Amazon cloud. To meet the needs of all the data engineers they moved to Amazon totally (Amazon Athena, Amazon Simple Storage Services, AWS Glue). They implemented datasets using algorithm to get new perspective.

Using AWS, BMW can handle large amount of data every day. With CDH connected to each vehicle they gained data in secure and get to know the health of the vehicle and resolve issues. With moving to AWS they managed data correctly and also provided the services for the customer's in their accounts.



Company 2:

- **Net Springs:**
- **Motivation and Significance:**

The main idea behind this is to connect to the cloud wherever you have your data without making duplication the data and analysis it.

- **Key findings/contributions:**

Net springs support all popular data clouds. After getting data here it forms relationship between streams and data models to get most from the data. The defined patterns of an object are by sequence and duration. We can customize the data without getting the raw data from SQL. We can also combine the blocks to get analytic computations.

The user defined block will have a unique logic. It also builds the time-based graphs. Based on the patterns user can also create segments of the object. There lots of different templates user can use. Some are visual oriented and some are based on the SQL and Net Script for special analysis.

From the graphs user can filter the data he needs. We can also track a product and understand the usage and other factors using dashboards. User can continuously watch and can create alerts with noise reduction control.

References:

13. https://aws.amazon.com/glue/?p=ft&c=aa&z=3
14. https://aws.amazon.com/solutions/case-studies/bmw-group-case-study/
15. https://www.netspring.io/product-behavioral-analytics/#querydirect

8. Reconfigurable Computing for Genomic Computations

Fundamental theory/ concepts:

By using the computable and statical analysis to get in depth biology concepts. Its is also use in the DNA and RNA. Computational and statistical approach to understand the function of the gene. With all the subsets this has become one and most important in the biology discovery.

How reconfigurable computing is useful in that area:

To get any DNA and RNA they should check all the possible outcome. this where reconfigurable computing comes into play.

Company 1:

- **Xilinx:**
- **Motivation and Significance:**

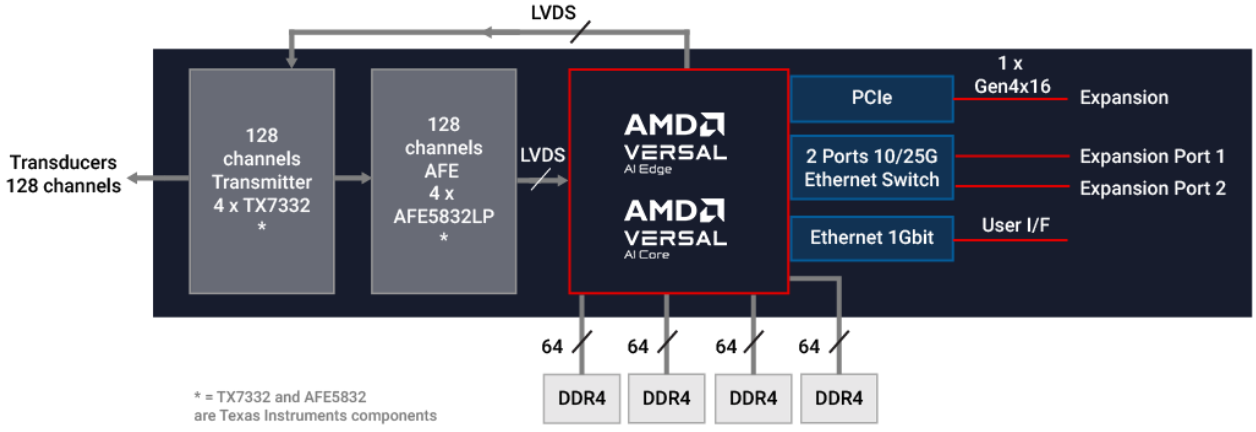
As patient care increases, they have to find new ways to find in the field of ultrasound.

- **Key findings/contributions:**

Ultrasound is used to find the high pixel images of scans in both deep and main factor to make successful solution for the cause. Speed serial transceivers makes the power consumption less also need for parallel IO; thus, it reduces the power.

Ultrasound design synthetic aperture and planar wave helps to more quality scans, with low cost and good thermal management. As the patient care increases the ultrasound need to maintain performance weather it is portable or connected.

With this have make better performance, image processing and battery life. with AI edge and Ai core running the synthetic aperture or planar wave with 120 active element's, 200 resolution lines in a chip and 100-1000 frames per second even for the smaller parts.



Company 2:

- **Illumina:**
- **Motivation and Significance:**

The main idea behind it is they have map different genomic keys in finding different tumor and cancer types.

- **Key findings/contributions:**

In USA and Canada alone using this they found about 33 various tumors and 10 rare cancer types. The module has two cells' formants and two maximum outputs. The quality data is required to find correct solution for the problem.

Each cell can operate separately. They can also run about 40-42 hours. One of the applications of NovaSeq 6000Dx which has correct target reaching capability. When people from use the probe on the DNA that comes from human cells or tissue.

They also developed with different partners to offer wider portfolio. this three-step workflow. Preparation, sequencing and analyzing data with DRAGEN server. This increases efficiency with increasing the number of samples.

References:

16. https://www.xilinx.com/applications/medical/medical-imaging-ultrasound.html
17. https://www.insideprecisionmedicine.com/news-and-features/clinical-ngs-boosts-prospects-for-widespread-personalized-medicine/

9. Reconfigurable Computing for Adaptive Cryptographic Systems

Fundamental theory/ concepts:

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How reconfigurable computing is useful in that area:

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Company 1:

- **Company Name:**

* *

- **Motivation and Significance:**

* *

- **Key findings/contributions:**

* *

Company 2:

- **Company Name:**

* *

- **Motivation and Significance:**

* *

- **Key findings/contributions:**

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References:

18. Topic citation 1 Source
19. Topic citation 2 Source

10. Reconfigurable Computing in Nanoscale Architectures

Fundamental theory/ concepts:

Nanoscale architectures are between the size of nano size and micro size. Which are developed in various ways. Most of this are 1 and 2 dimensional. It also come with great properties and fabrication need to be done with almost care and need to be of good quality. This also effect on mechanical and physical properties.

How reconfigurable computing is useful in that area:

With implementing reconfigurable computing in this area we can achieve getting good computing platform, have less manufacture risks, increasing in performance and reducing power usage.

Company 1:

- **Xilinx:**

- **Motivation and Significance:**

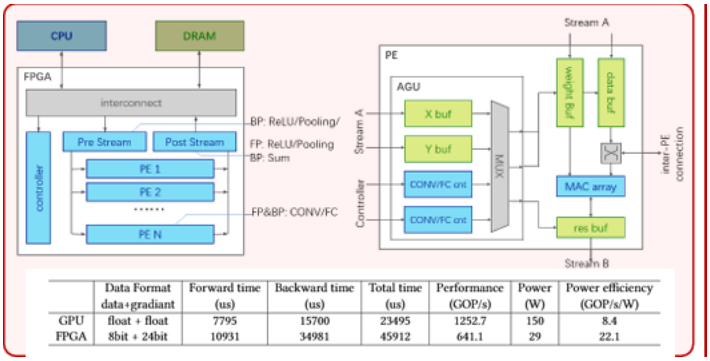
They want find solution for the early-stage risk, matrix transportation and loop dimensions.

- ## Key findings/contributions:

They created a process which is hardware friendly with quantization and pruning. Dedicated processing elements on FPGA to help with operator and results patterns. They also designed loop mapping for both FP and BP.

It has three times better energy efficient when compare with GPU. DNNVM is a end to end that transforms the graphs into domain specific graphs. Based on the graphs they have created some templates to take over the operation.

They also did a subgraph algorithm in which they can check the performance in between steps. With this it speeds up by twice when compare with the base line.



	Data Format data+gradiant	Forward time (us)	Backward time (us)	Total time (us)	Performance (GOP/s)	Power (W)	Power efficiency (GOP/s/W)
GPU	float + float	7795	15700	23495	1252.7	150	8.4
FPGA	8bit + 24bit	10931	34981	45912	641.1	29	22.1

Company 2:

- ## Quick logic:
- ## Motivation and Significance:

The idea behind this project is finding the solutions for the embedded systems architecture challenges.

- ## Key findings/contributions:

Using the polar pro 3 FPGAs has a smaller size, better utilization and low power usage. This is a perfect solution for chip-to-chip connection, power usage, lag in the system and market time. Polar pro 3 is available in the market to connect, sensor control and applications.

Polar pro 3 is a battery power application and flexible to reprogram to required for the application. Application such as shifting, CPU cores, low speed protocols which are mostly fount in the IOT applications.

This solved most of the challenges that are faced the embedded systems architecture. some of the features are reprogrammable SRAM, supported by open source and integrated embedded block.

References:

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21. **https://www.quicklogic.com/products/fpga/fpgas-sram/**

11. Domain-specific computing

Fundamental theory/ concepts:

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How reconfigurable computing is useful in that area:

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Company 1:

- **Company Name:**

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- **Motivation and Significance:**

* *

- **Key findings/contributions:**

* *

Company 2:

- **Company Name:**

* *

- **Motivation and Significance:**

* *

- **Key findings/contributions:**

* *

References:

22. Topic citation 1 Source
23. Topic citation 2 Source

12. Multi-FPGA Systems

Fundamental theory/ concepts:

In a multi-FPGA system, it can be multi board system or many FPGA on one board but they are connected with each other. This also have high frequency and we can-do real-time testing. This can also be used as functional Verification of the prototype. Parting is the one of the difficult steps in this systems. It also offer better speed and simulation based solutions.

How reconfigurable computing is useful in that area:

Reconfigurable computing comes into play when their different FPGA doing different works at same time.

Company 1:

- **Opal Kelly:**
- **Motivation and Significance:**

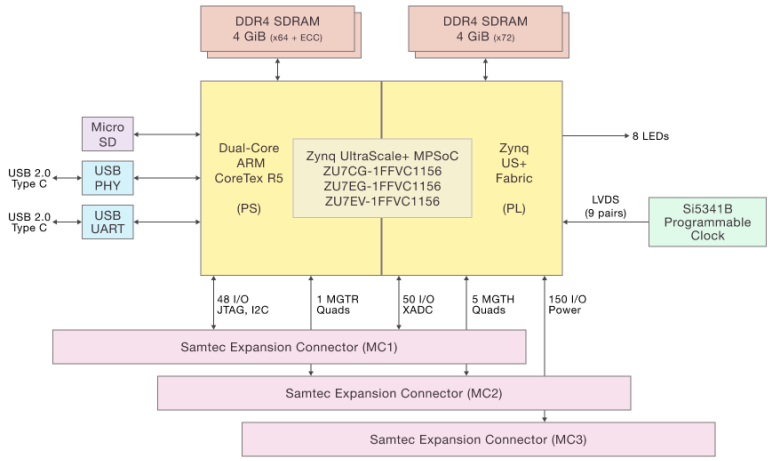
They want build a module that which is high-integrated, high performance and compact FPGA board.

- **Key findings/contributions:**

The module ECM1900 that had designed for data acquisition, instruments and analytics workloads. This module is created in such way that it will support, power distribution through out the system and on the memory.

This follows the ISO 9001:2015 production and quality management system which has the low or mid volume production in testing the equipment, instrumental and control.

Some of the feature of this are both the CPU memory and FPGA memory has 72 bits. MGTH of FPGA and CPU has speed interfaces. It has only one input which is about 5-15V and it is also have easy distribution.



Company 2:

- **Intel:**
- **Motivation and Significance:**

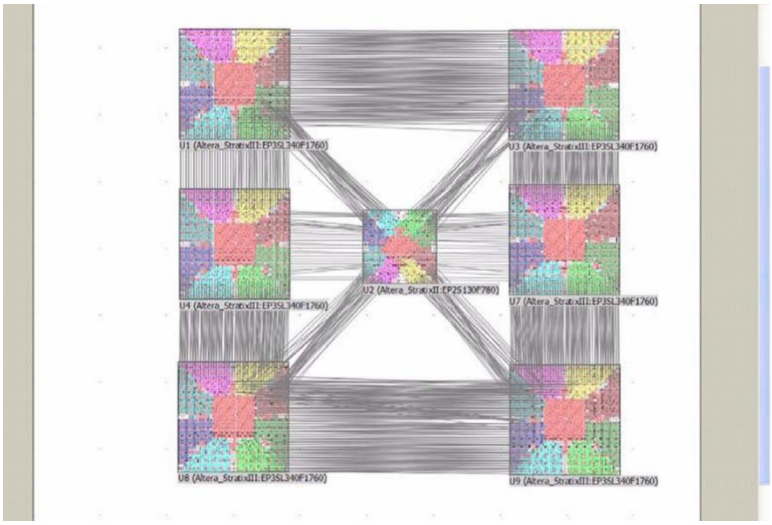
They want develop a model which can used in different applications.

- **Key findings/contributions:**

They have work on different projects but they end up making the circuit complicate. Managing the multi-FPGA has created new challenges. they come up with three methods but every method has their own advantages and disadvantages.

First is creating the master design and divide it into and giving it to different engineers. Secondly, working from bottom up handling each section separately. Third is splitting it into smaller sections and combining it.

In this specific product they used six altera which are connected in the ring fashion using 256 bits and connected with middle with 32 signals. Some of the features of altera EP3SL340F1760 FPGA is it has 1760 pins, frequency is about 600MHz, memory and RAM size is 2.2 MB.



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26. https://www.intel.com/programmable/technical-pdfs/654293.pdf

Team member contributions:

Kavya Sree Maddikara : Topics 1, 2, 3, 4, 5

Joshua Sannareddy : Topics 6, 7, 8, 10, 12