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THE EVOLUTION OF INTEL PROCESSOR'S GENERATIONS

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ABSTRACT

The concept of the computer processor was proposed in the 1950s and applied to computer capacity. Here we analyze the Intel computer processors evolution. It is shown that during the transition "from old to new" the manufacturers change the parameters, functionality, and capacity. It directly affects the computer performance and computer processing capacity. Intel processors are used as the main example due to their high popularity and the accessibility of detailed descriptions of all the technical characteristics.

Keywords: Computer Capacity, Processors, Performance Evaluation, Intel Processors Generation.

I. INTRODUCTION

In today's world processors are widely used in electronic devices. Such as mobile phones, computers, laptops, and many other devices. Their performance, processing capacity, and accessibility have grown over the last 5 to 6 decades. There are many manufacturers of computer processors but the Intel processors are more popular because of their processing results and variety of processor capacity. In the context of such rapid development, it is interesting to find the way of Intel processor evolution. For this, one needs to be able to estimate the influence of changing some characteristics of a processor on its performance.

Federico Faggin

The first microprocessor was made by sir Federico Figgins in 1971. The 4004 was the first complete CPU on a single chip, packaged in a 16-pin ceramic dual in-line package. The 4004 was initially released with a clock speed of 108 kHz (and scaled up to 740 kHz). Produced in a 10 µm (10,000 nm) process, the 4004 had 2,300 transistors and delivered a performance of 0.07 MIPS. The 8-bit 8008 replaced the 4004 in 1972 with 0.5 to 0.8 MHz clock speed and 3,500 transistors and was primarily used in the TI 742 computer. The 8080 followed in 1974 with 4,500 transistors in 6,000 nm with up to 2 MHz It became famous for being used in the Altair 8800, as well as in Boeing's AGM-86 cruise missile [1].

Nowadays designers must have a real model and set of benchmarks to estimate the performance of the developed processor. It requires some time to prepare the physic model of the processor and spend time calculating. A theoretical approach to estimating computer capacity was suggested in [2]. This approach uses only the description of the investigated computer architecture. The latter includes the set of instructions, features of their execution, sizes of all the memory types, etc.

In this paper, we consider the evolution of Inter processors over the last 50 years [3]. I show that each processor can be represented as a set of parameters and changing some of these parameters has a significant effect on its performance. My investigation shows that the new processor of Intel usually increases the characteristics which affect the computer capacity most. It's worth noting that there are distinct trends in the development of processors over the last 50 years. The first noticeable trend is an increase in clock rate, which results in a reduction in job execution time. The second is the broad implementation of parallelism, which includes expanding the number of processors in computers, expanding the number of computational cores in processors, and adding threads and pipelines, among other things. It is obvious that the impact of these variables is enormous, but it is also evident. We show that when new processors are deployed, designers change precisely those characteristics that have a substantial impact on computer capacity. This is why we

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focus on a single company's processors, assuming that designers maintain consistency and deliver new processors that improve on earlier models.

II. METHODOLOGY

Computer capacity:

Let us consider a computer with the set of instructions I and memory M. An instruction $x \in I$ is formed as the combination of its name and the values of its operands (two instructions with the same names and different values of operands are both included in I). For example, instruction mov eax and mov eax, ecx are different and included in I independently. A computer task X is a sequence of instructions $X = x1, x2, \dots, xi \in I$ It is important to note that if there is a loop in ta ask which is repeated m times, the body of this loop included m times in X. We denote τ (x) the execution time of instruction x. So, the execution time of a computer task X is given by $\tau(x) = \sum_{i=1}^{n} \tau(xi), X = x1, x2, \dots, xn$. Let consider the number of all possible computer tasks which execution times equal to T as $N(T) = |\{X: \tau(X) = T\}|$Furthermore, let there be a processor which has exactly N1 different tasks with execution times equal to, for example, 1 hour. In this case we can say that it can execute N_1^2 different tasks in 2 hours because if X1 and X2 are 1-hour tasks, the combined task S1S2 is the 2-hour one (we did not take into account the 2-hour tasks with instruction starts at the end of the first hour and finishes and the beginning of the second). In this way, the considered processor has $\approx N_1^k$ tasks with execution times k hours. So we claim that the number of possible tasks grows exponentially as a function of time $(N(T) \approx 2^{CT})$. Thereby, $C = \log(N(T))/T$ (or rather the limit of this value) is the adequate measure of the computer capacity and it defines as follows:

$$C(I) = \lim_{T \to \infty} (\log N(T)/T)$$

The main question here is how to estimate the value of C(I) from (1). The direct calculation of the limit is impossible, but there exists the method of calculation the capacity C(I) in combinatorial analysis. In this case we consider the set of instructions I as an alphabet and assume that all words (sequences of instructions) over this alphabet are possible (can be executed). This assumption allows us to estimate an upper-bound of the computer capacity, because for any processor the set of its permissible tasks is the subset of all possible tasks. Here, all execution times are integers (this statement is valid for the most of processors). The way of estimation of the capacity was suggested by C. Shannon [4], who showed that the capacity C(I) is equal to the logarithm of the largest real solution Y0 of the following characteristic equation:

$$y^{-\tau(x1)} + Y^{-\tau(x2)} + \dots + Y^{-\tau(xn)} = 1$$

In [3] it was also shown that the computer capacity of multi-core processing unit can be defined as the sum of capacities of the cores.

III. MODELING AND ANALYSIS

Analysis of Intel Processor Evolution

Evaluates the performance and up-gradation of elements from the first to four generations of Intel processors [1], and table 1 shows their upgraded parameters.

Table 1

Generation	Process Size	Transistor	Clock speed	Cores	Cache	Sockets	RAM	GPU	Intel Turbo Boost
Nehlam 1st	45nm	731 million to 2300 million	1.06 GHz to 3.33 GHz	2-6 in normal/4-8 in Xeon	**L1 cache:** 64 KB per core,**L2 cache**: 256KB per core,**L3 cache:** 4 MB-24 MB shared by all cores	LGA 1156, LGA 2011, Socket G2	2-channel DDR3-1066		1
Sandy Bridge 2nd	32nm	504 million to 2.27 billion	1.60GHz to 3.60 GHz	1-4 in normal/4-6 in extreme/2-8 in Xeon	**L1 cache:** 64 KB per core,**L2 cache:** 256KB per core,**L3 cache:** 1 MB-8 MB shared by all cores/10 MB-15 MB in extreme/3 MB-20 MB Xeon	LGA 1155, LGA 1366, LGA 1567	2-channel DDR3	HD graphics, HD graphics 2000, HD graphics 3000, HD graphics P3000	2
Ivy bridge 3rd	22nm	2104 million	1.4GHz to 4.1 GHz	2-4 in normal/2-15 in Xeon	**L1 cache:** 64 KB per core,**L2 cache:** 256KB per core,**L3 cache:** 2 MB-8 MB shared by all cores	LGA 1155, LGA 2011, LGA 2011-1, LGA 1356, Socket G2	DDR3-1333 to DDR3-1600	HD graphics 2500, HD graphics 4000, HD graphics P4000	2
Haswell 4th	22nm	1.4 billion to 5.	1.1GHz to 4.4 GHz	2-4 in normal/6-8 in enthusiast/2-18 in Xeon	**L1 cache:** 64 KB per core,**L2 cache:** 256KB per core,**L3 cache:** 2 MB-45 MB shared by all cores,L4 cache: 128 MB (iris Pro only)	LGA 1150, rPGA 947, LGA 2011-v3	Dual channel DDR3/ DDR3L, DDR4	HD graphics 4200, HD graphics 4400, HD graphics 4600, HD graphics 5000, Iris 5100, Iris Pro 5200	2

The evolution of the 1st to 4th generation of Intel processor Table (1)

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Modeling and Analysis:

Table 2

Generation	Process Size	Transistor	Clock speed	Cores	Cache	Sockets	RAM	GPU	Intel Turbo Boost
Haswell 4th	22nm	1.4 billion to 5.	1.1GHz to 4.4 GHz	2-4 in normal/6-8 in enthusiast/2-18 in Xeon	**L1 cache:** 64 KB per core,**L2 cache:** 256KB per core,**L3 cache:** 2 MB-45 MB shared by all cores,L4 cache: 128 MB (iris Pro only)	LGA 1150, rPGA 947, LGA 2011-v3	Dual channel DDR3/ DDR3L, DDR4	HD graphics 4200, HD graphics 4400, HD graphics 4600, HD graphics 5000, Iris 5100, Iris Pro 5200	2
Broad well 5th	14nm	1.9 billion	1.2GHz to 4GHz	2-4 in normal/6-10 in enthusiast/4-24 in Xeon	**L1 cache:** 64 KB per core,**L2 cache:** 256KB per core,**L3 cache:** 2 MB-6 MB shared by all cores,L4 cache: 128 MB (iris Pro only)	LGA 1150, rPGA 947, LGA 2011-v3	DDR3, DDR3L, DDR4	HD graphics 5300, HD graphics 5500, HD graphics 5700p, HD graphics 6000, HD graphics 6100, HD graphics 6200, HD graphics 6300p, HD graphics	3

According to table (2) when we compare the process size of the 4th and 5th generations, we can see that the process size of the 4th generation is 22nm while that of the 5th generation has been slightly reduced to 14nm. Now when we look at the transistor for the 4th generation the parameters are between 1.4 billion to 5 billion and for the 5th generation, there is an increase in parameters to 1.9 billion. This will help in better functioning as compared to the 4th generation. The clock speed of the Haswell is 1.1 to 4.4 GHz and the Broad well is 1.2GHz to 4 GHz we can see in their clock speed rate a slight increase. In the cache memory and sockets of both generations, it remained the same. But the RAM and GPU (Graphical Processing Units) are slight updates in Broad well. In the last section, we can see the Intel turbo boost is updated in broad well 6th generation.

Table 3

Generation	Process Size	Transistor	Clock speed	Cores	Cache	Sockets	RAM	GPU	Intel Turbo Boost
Broad well 5th	14nm	1.9 billion	1.2GHz to 4GHz	2-4 in normal/6-10 in enthusiast/4-24 in Xeon	**L1 cache:** 64 KB per core,**L2 cache:** 256KB per core,**L3 cache:** 2 MB-6 MB shared by all cores,L4 cache: 128 MB (iris Pro only)	LGA 1150, rPGA 947, LGA 2011-v3	DDR3, DDR3L, DDR4	HD graphics 5300, HD graphics 5500, HD graphics 5700p, HD graphics 6000, HD graphics 6100, HD graphics 6200, HD graphics 6300p, HD graphics	3
skylake 6th	14nm	1.9 billion	up to 4.5GHz	2–28	**L1 cache:** 64 KB per core,**L2 cache:** 256KB per core,**L3 cache:** 2 MB per core,**L4 cache:** 128 MB (iris Pro only)	LGA 1150, rPGA 947, LGA 2011-v3	DDR3, DDR3L, DDR4	HD 530, Iris Pro 580, HD 510, Iris 540, HD 520, HD 550, Iris 550, HD 515	3

Table (3) compares the process sizes of the 5th and 6th generations, revealing that the 5th generation's process size and transistor count are identical. Broadwell clock speeds range from 1.2 to 40 GHz, while Skylake clock speeds reach 4.5 GHz, showing a little rise in clock speed rate. The cache memory and sockets in both versions remained the same. Skylake, on the other hand, features minimal RAM and GPU (Graphical Processing Unit) upgrades. As we saw in the previous section, Intel turbo boost is the same in Skylake 6th generation.

Table 4

Generation	Process Size	Transistor	Clock speed	Cores	Cache	Sockets	RAM	GPU	Intel Turbo Boost
skylake 6th	14nm	1.9 billion	up to 4.5GHz	2–28	**L1 cache:** 64 KB per core,**L2 cache:** 256KB per core,**L3 cache:** 2 MB per core,**L4 cache:** 128 MB (iris Pro only)	LGA 1150, rPGA 947, LGA 2011-v3	DDR3, DDR3L, DDR4	HD 530, Iris Pro 580, HD 510, Iris 540, HD 520, HD 550, Iris 550, HD 515	3
kaby lake 7th	14nm		1.0GHz to 4.5GHz	2–4	**L1 cache:** 64 KB per core,**L2 cache:** 256KB per core,**L3 cache:** 8 MB shared	LGA 1151, LGA 2066, BGA 1356, BGA 1440, BGA 1515	DDR3, DDR3L, DDR4(upto 64GB)	HD 630, HD 610, HD 615, HD 620, Iris Plus 640, Iris Plus 650, HD P630, UHD 620, UHD 615, UHD 617, UHD	3

Table (4) shows that the process sizes of the 6th and 7th generations are the same. However, because the Kaby lake generation's chip is smaller than the previous generation's, the transistor is eliminated. Skylake and Kaby Lake have the same clock speed. Kaby Lake has fewer cores and cache memory components than Skylake. However, the number of sockets, RAM, and GPU units in the 7th generation of Intel processors is higher than in Skylake. In all generations, however, Intel Turbo Boost stayed the same. The transistors have been eliminated from Intel processors since the 7th generation.

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Table 5

Generation	Process Size	Transistor	Clock speed	Cores	Cache	Sockets	RAM	GPU	Intel Turbo Boost
kaby lake 7th	14nm		1.0GHz to 4.5GHz	2–4	**L1 cache:** 64 KB per core,**L2 cache:** 256KB per core,**L3 cache:** 8 MB shared	LGA 1151, LGA 2066, BGA 1356, BGA 1440, BGA 1515	DDR3, DDR3L, DDR4(upto 64GB)	HD 630, HD 610, HD 615, HD 620, Iris Plus 640, Iris Plus 650, HD P630, UHD 620, UHD 615, UHD 617, UHD	3
kaby lake R 8th	14nm		1.0GHz to 4.5GHz	2–4	**L1 cache:** 64 KB per core,**L2 cache:** 256KB per core,**L3 cache:** 8 MB shared	LGA 1151, LGA 2066, BGA 1356, BGA 1440, BGA 1515	DDR3, DDR4(up to 64GB)	HD 630, HD 610, HD 615, HD 620, Iris Plus 640, Iris Plus 650, HD P630, UHD 620, UHD 615, UHD 617, UHD	3

Table (5) shows that the process sizes, clock speed, cache, and Sockets of the 7th and 8th generations are identical. The capacity of the RAM of Kaby lake (R)research is much better than Kaby lake. In both generations, however, Intel Turbo Boost stayed the same.

Table 6

Generation	Process Size	Transistor	Clock speed	Cores	Cache	Sockets	RAM	GPU	Intel Turbo Boost
kaby lake R 8th	14nm		1.0GHz to 4.5GHz	2–4	**L1 cache:** 64 KB per core,**L2 cache:** 256KB per core,**L3 cache:** 8 MB shared	LGA 1151, LGA 2066, BGA 1356, BGA 1440, BGA 1515	DDR3, DDR4(up to 64GB)	HD 630, HD 610, HD 615, HD 620, Iris Plus 640, Iris Plus 650, HD P630, UHD 620, UHD 615, UHD 617, UHD	3
Coffe Lake Refresh 9th	14nm		1.8GHz to 5GHz	2–8	**L1 cache:** 64 KB per core,**L2 cache:** 256KB per core,**L3 cache:** 16 MB shared	altered LGA 1151 with more core support	DDR4-2666 2-channel up to 128 GB	GT2, GT3e	3

The process size is the same in both generations, as shown in Table (6). Kaby Lake R has a clock speed of 1.0 GHz to 4.5 GHz, whereas Coffe Lake Refresh has a clock speed of 1.8GHz to 5GHz. We consider the 9th generation's clock speed to be superior than that of Kaby Lake R. We can also notice that the cache and Ram of the Coffe Lake Refresh are nearly double that of the Kaby Lake R. The sockets and GPU of the 9th generation are more advanced than the Kaby Lake R sockets. The Intel turbo boost, on the other hand, is the same in both models.

Table 7

Generation	Process Size	Transistor	Clock speed	Cores	Cache	Sockets	RAM	GPU	Intel Turbo Boost
Coffe Lake Refresh 9th	14nm		1.8GHz to 5GHz	2–8	**L1 cache:** 64 KB per core,**L2 cache:** 256KB per core,**L3 cache:** 16 MB shared	altered LGA 1151 with more core support	DDR4-2666 2-channel up to 128 GB	GT2, GT3e	3
Comet lake/ Ice lake10th	14nm(desktop)/10nm(mobile)		up to 5.3 GHz(desktop)/ 4.1 GHz(mobile)	2-10(desktop)/2-4(mobile)	**L1 cache:** 64 KB per core(desktop)/80kb per core(mobile),**L2 cache:** 256KB per core(desktop)/512kb per core (mobile),**L3 cache:** 20 MB shared(desktop)/8 MB shared(mobile)	BGA1526, LGA 1200	Up to LPDDR4X at 3733 MHz	Gen11 based	3

The process size is the same in both generations, according to the table (7), but in the 10th generation, the Comet Lake/Ice Lake process size is defined for two electronic devices that are commonly used currently. The clock speed, cores, cache, sockets, RAM, and GPU are all improved in the 10th generation, as are the clock speeds, cores, and cache speeds for mobile devices. Intel turbo boosts are equivalent in both generations.

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Table 8

Generation	Process Size	Transistor	Clock speed	Cores	Cache	Sockets	RAM	GPU	Intel Turbo Boost
Comet lake/ Ice lake10th	**14nm(desktop)/10nm(mobile)**		up to 5.3 GHz(desktop)/ 4.1 GHz(mobile)	2-10(desktop)/2-4(mobile)	**L1 cache:** 64 KB per core(desktop)/80kb per core(mobile),**L2 cache:** 256KB per core(desktop)/512kb per core (mobile),**L3 cache:** 20 MB shared(desktop)/8 MB shared(mobile)	BGA1526, LGA 1200	Up to LPDDR4X at 3733 MHz	Gen11 based	3
Tiger lake/Rocket Lake 11th	**14nm(desktop)/10nm(mobile)**		up to 5.3 GHz(desktop)/ 5 GHz(mobile)	up to 8(desktop)/2-8(mobile)	**L1 cache:** 64 KB per core(desktop)/80kb per core(mobile),**L2 cache:** 512KB per core(desktop)/1.25 MB per core (mobile),**L3 cache:** 16 MB shared(desktop)/24 MB shared(mobile)	LGA 1200, FCBGA1449, FCBGA1787	DDR4-3200/LPDDR5-5400	Gen12 based	3

The process size in both generations for mobile and desktop is the same, according to the table (8). Tiger Lake/ Rocket Lake brings improvements to clock speed, cores, cache, sockets, and RAM. The Comet Lake/ Ice Lake's graphic processing unit is based on Gen 11 technology, whereas the Tiger Lake/ Rocket Lake's graphic processing unit is based on Gen 12. The eleventh generation upgrades the entire generation of graphics processing units. However, in both generations, Intel turbo boosts are the same.

IV. RESULT AND DISCUSSION

We've made some observations on each generation of Intel processors based on the model and analysis section. The transistors, RAM, cache memory components, and many other components of Intel processors are changed or updated with each iteration. Above and above anything we've seen in the last 50 years.

Every version of Intel processor has more transistors for improved power delivery, as can be shown. They also changed the size of the process, the clock speed, and the number of cores for improved performance. They also increased the cache capacity in each generation for easier access to recent data and programs. Because it improves CPU access and eliminates harm when a unit is inserted or removed, the number of sockets and their capacity would expand. A CPU socket also features a lock to keep the CPU from moving about, and its design aids in heat sink placement above the CPU. Random-Access Memory's power and capacity are also increasing, allowing for faster memory access. The Graphical Processing Unit's quality and several measures were also upgraded for better picture quality.

V. CONCLUSION

After I've presented all of the findings, I'll be able to draw some conclusions. Tiger Lake/ Rocket Lake is the last microarchitecture to be evaluated. The Tiger Lake microprocessor architecture is the most recent in Intel's CPU history. It is equipped with more advanced features than any previous Intel CPU version. In comparison to previous generations, the tiger lake's functioning and performance are more flexible. It is built with higher-quality components than other Intel processors. Table 8 shows all of its components and advanced parts. Intel generation 11 features a larger memory capacity for accessing data, as well as several innovative components. We also notice that RAM and cache boost the computer's performance. We've also seen that the number of transistors and registers has increased insignificantly over the last 15 years, so we expect this trend to continue in new processors, with the number of registers vector increasing for higher processing quality. As a result, we can expect the number of internal registers, transistors, and other parts in the next processor microarchitecture to increase in order to improve performance.

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