Microprocessor & Computer Architecture (μpCA)

UE19CS252

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Unit 5: Advanced Architecture

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Syllabus

~~Unit 1: Basic Processor Architecture and Design~~

~~Unit 2: Pipelined Processor and Design~~

~~Unit 3: Memory~~

~~Unit 4: Input/Output Device Design~~

Unit 5: Advanced Architecture

- ~~Need for High Performance Computing~~
- ~~Classification of Parallel Architectures~~
- ~~Shared Memory Vs Distributed Memory Programming Paradigm.~~
- ~~Bird Eye View of Parallel Architectures~~
- ~~Parallel Processing~~
- **Amdahl’s Law & Gustafson’s Law**

Amdahl's Law
&
Gustafson's Law

Speedup- Parallel Architecture

- Speedup is the most often used measure of parallel performance
- If
  - T_s is the best possible serial time
  - T_n is the time taken by a parallel algorithm on *n* processors
- Then
  - $$Speedup = \frac{T_s}{T_n}$$

Example:

If T1 is time taken to execute program on 1 Processor.

Then T1/N is time taken to execute program on N=2 Processor

If T1=1 then TN= 0.5

Thus the speed up is 2

Is it worth?

Example

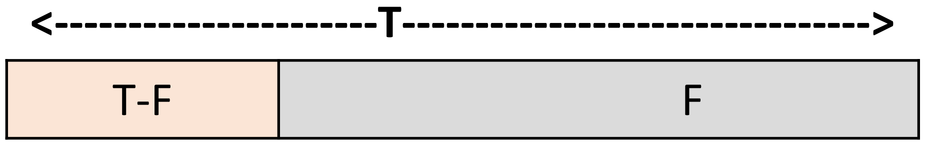
Processors	Time(secs)	Speedup	Efficiency
1	76	1.00	1.00
2	38	2.00	1.00
4	20	3.80	0.95
5	16	4.75	0.95
6	14	5.42	0.90
8	11	6.90	0.86
9	10	7.60	0.84

Truth of Parallel Execution

A program (or algorithm) which can be parallelized can be split up into two parts:

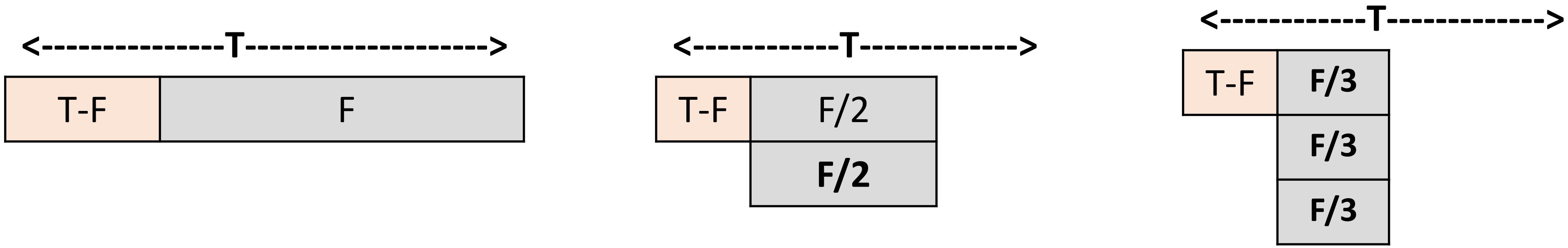
- **A part which cannot be parallelized**
- **A part which can be parallelized**

- T = Total time of serial execution
- T-F = Total time of non-parallizable part
- F = Total time of parallizable part (when executed serially, not in parallel)



$T = F + (T-F)$

Truth of Parallel Execution



$T = (T-F) + F$

$(F)/N$

$T(N) = (T-F) + F/N$

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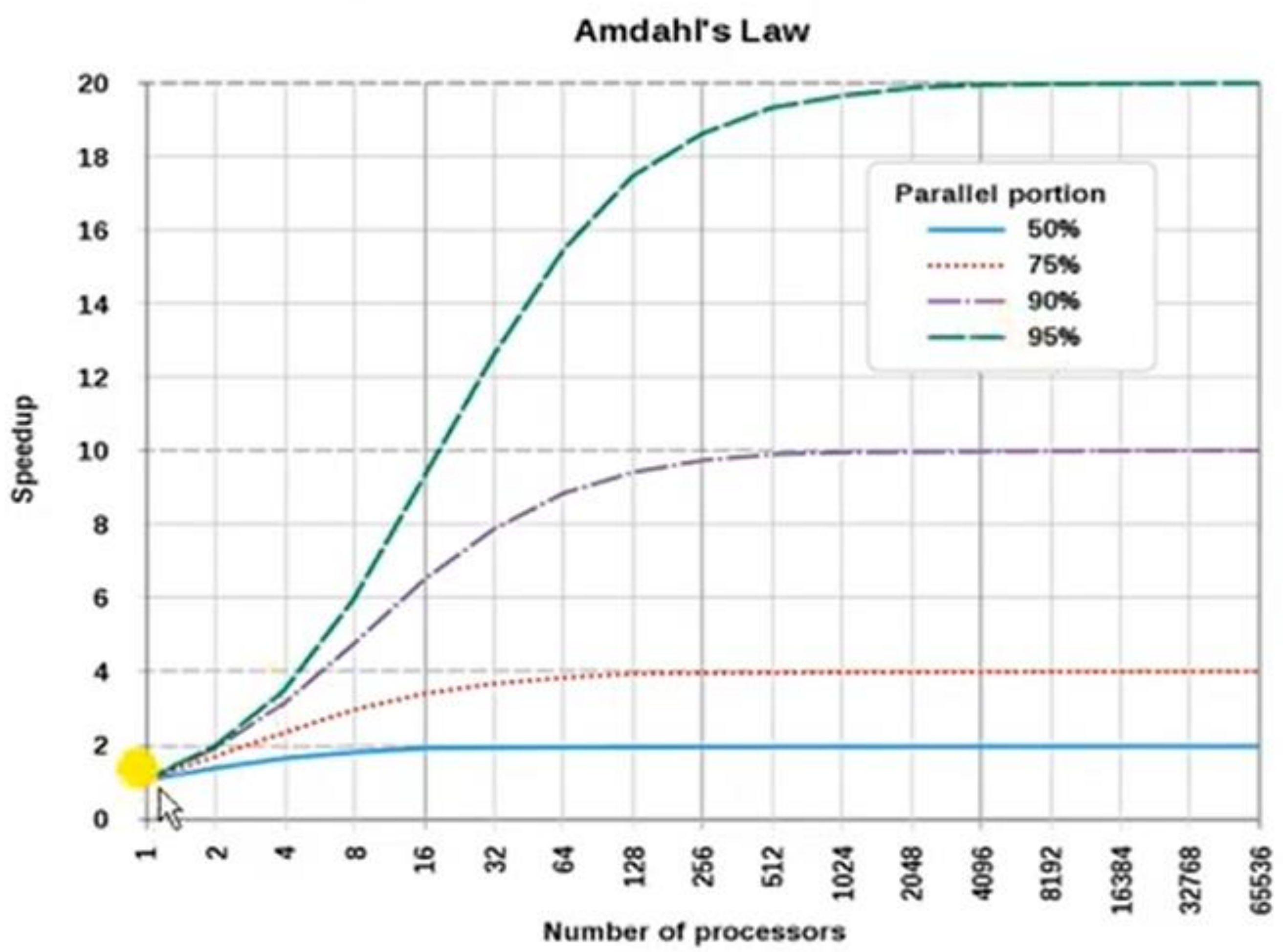

Amdahl's Law

Amdahl's law states that the maximum speedup possible in parallelizing an algorithm is limited by the sequential portion of the code.

It's a Measure, but not Calculation

Speedup = TS/TN

= TS/(1-F)TS+(F/N)TS

= **1/(1-F)+(F/N)**

or

Speedup= S+F/S+(F/N)

= **1/(1-F)+(F/N)**

TS= S + F

S=TS-F

If TS= 1

S=1-F

Example:

If N= 10, F=60%

Then

Speed up = 1/0.4+(0.6/10)

= 2.17

Example:

If N= 10, F=90%

Then

Speed up = 1/0.1+(0.9/10)

= 5.26

Example: Impossible case

If N= 10, F=99%

Then

Speed up = 1/.1+(.99/10)

= 9.17

Rough Work:

(1-f)+(f/n) x TS

(TS-TSxf) + (F/N)xTS

(1-f)xTS +(F/N)x TS

Example

Consider summing 10 scalar variables and two 10 by 10 matrices (matrix sum) on 10 processors.

Add=a+b+c+d+e+f+g+h+i+j;

Sum0= a[0][j]+b[0][j]

Sum1= a[1][j]+b[1][j]

…………………………………………

Sum9= a[9][j]+b[9][j]

100 parallèl exécution

10 non –parallèl exécution

Solutions

Total of 110 opérations

100/110= 0.909 Parallelizable

10/110= 0.091 non –parallelizable or (1-909=0.091)

On 10 processor	On 100 processor
Speedup = 1/(.091 + .909/10) = 1/0.1819 = 5.5	Speedup = 1/(.091 + .909/100) = 1/0.10009 = 10.0

Amdahl's law is a fatal limit to the usefulness of parallelism.

Amdahl's law usually overestimates speedup achievable

- Do not consider Size of the Program
- Ignores communication cost

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Gustafson’s Law

Gustafson’s Law

Gustafon’s Law: The proportion of the computations that are sequential, normally decreases as the problem size increases.

Note Gustafson’s law is a “observed phenomena” and not a theorem

- Rather than assuming that the problem size is fixed, assume that the parallel execution time is fixed.
- As problem size is increases, increase the parallel processing units (N).
- Gustafson, makes the case that the serial section of the code does not increase with the problem size.

A Driving Metaphor

Amdahl's Law approximately suggests:

“ Suppose a car is traveling between two cities 60 miles apart, and has already spent one hour traveling half the distance at 30 mph. No matter how fast you drive the last half, it is impossible to achieve 90 mph average before reaching the second city. Since it has already taken you 1 hour and you only have a distance of 60 miles total; going infinitely fast you would only achieve 60 mph. ”

Here Fixed Distance is Code size. Amdahl’s law assumes code size to be constant.

Gustafson's Law approximately states:

“Suppose a car has already been traveling for some time at less than 90mph. Given enough time and distance to travel, the car's average speed can always eventually reach 90mph, no matter how long or how slowly it has already traveled. For example, if the car spent one hour at 30 mph, it could achieve this by driving at 120 mph for two additional hours, or at 150 mph for an hour, and so on.”

Here, it is assumed that the Distance may vary, as the distance is more, chances of increased speedup is more

A Driving Metaphor

Amdahl's Law approximately suggests:

Problem: To travel from Parking area to University Gate in 500 CC Bullet

Step1: Reach the ***parking area gate*** in the speed 30 KM per hour
Step 2: Reach the ***University Main Gate*** 90 Km per hour.
Question: Did you reach fast? Though your speed was 90 Km/Hour in 500 CC Bullet?

Here Fixed Distance is Code size. Amdahl's law assumes code size to be constant.

Gustafson's Law approximately states:

Problem: To travel from Parking area to House in 500 CC Bullet

Step1: Reach the ***parking area gate*** in the speed 30 KM per hour
Step 2: Reach the **House** 90 Km per hour.
Question: Did you reach fast? when your speed was 90 Km/Hour in 500 CC Bullet, though your speed was 30 Km/hour to reach ***parking area gate***?

Here, it is assumed that the Distance may vary, as the distance is more, chances of increased speedup is more

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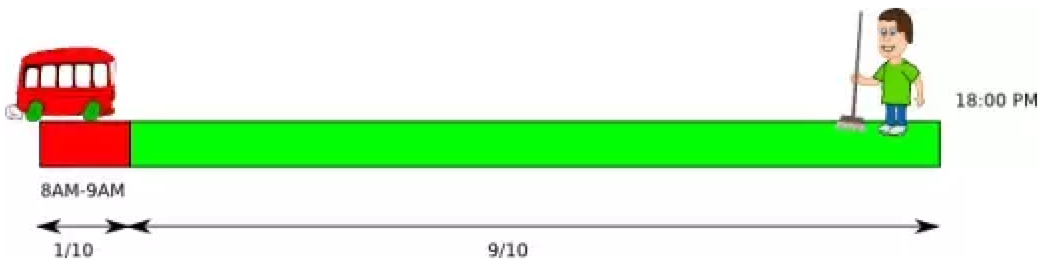
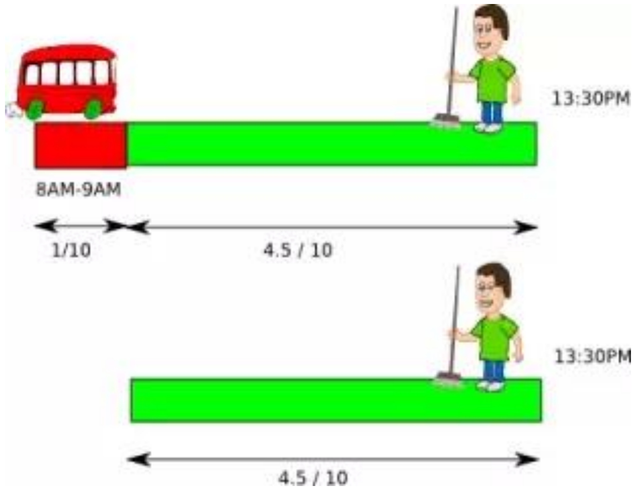
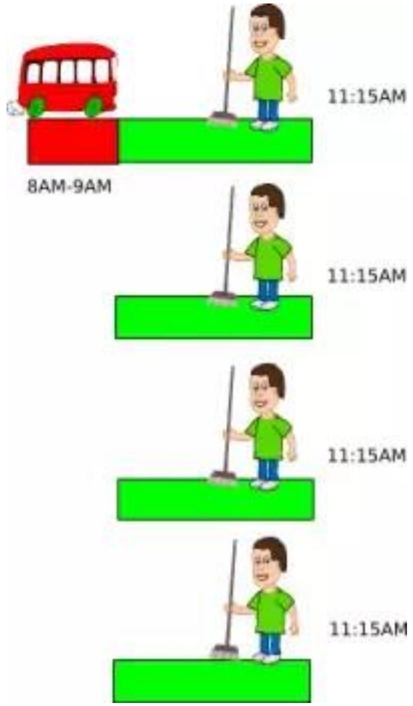
Amdahl’s Law

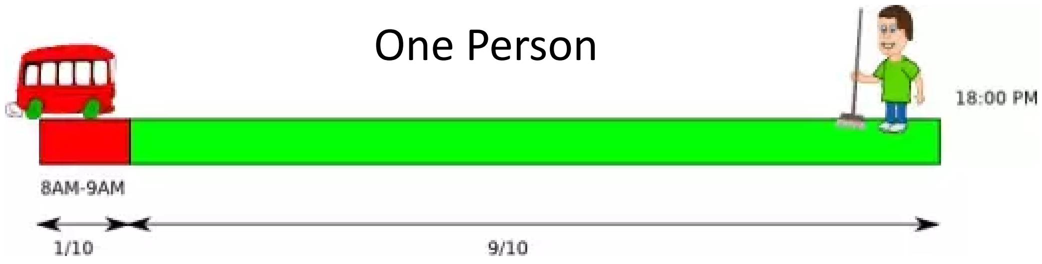




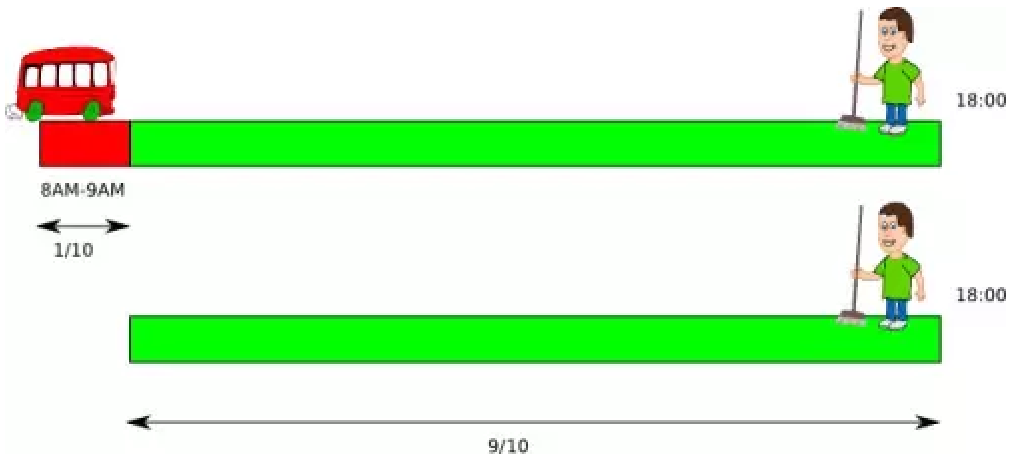


Gustafson’s Law

One Person

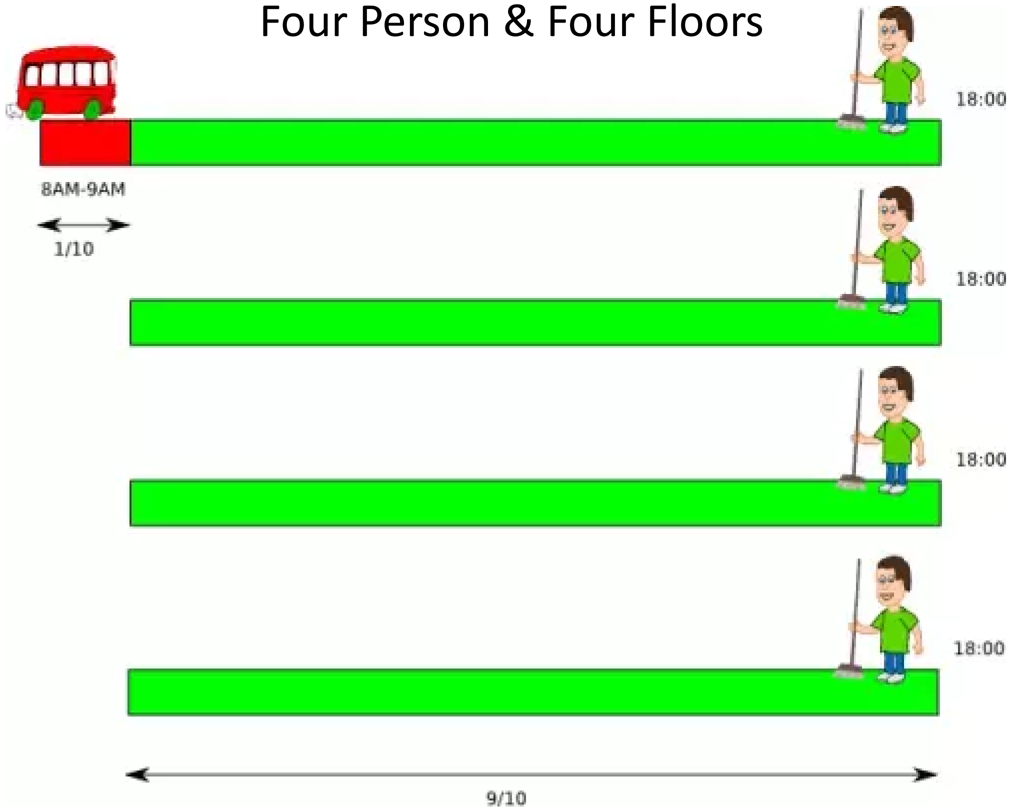


Two Person & Two Floors



Time Calculation = 2-1*(1/10)= 1.9 times speed of 1 person

Four Person & Four Floors



Time Calculation = 4-3*(1/10)= 3.7 times speed of 1 person

Gustafson's Law

The speed up factor is= $N-(N-1)*S$

$= N+(1-N)*S$

The speed up factor is called Scaled Speed-up Factor

Amdahl's Law vs Gustafson's Law

Suppose a serial section of 5% and 20 processors;

Gustafon's Law

Speed-up = 20 + (1-20)*0.05
=20-0.95
=19.05

Amdahl's Law

Speed-up = 1/0.05 + (0.95/20)
=10.25

Reference

https://www.cse.iitd.ac.in/~rijurekha/col380/performance2.pdf

https://www.quora.com/Can-you-explain-Amdahls-Law-and-Gustafsons-Law

Next Session

Multicore Processor

An Outcome of Gustafson's Law

THANK YOU

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