McCloud
Service Framework

PUC
RIO

Monte Carlo Service in Windows Azure

Rafael Nasser <rnasser@inf.puc-rio.br>
Karin Breitman <karin@inf.puc-rio.br>
Hélio Lopes <lopes@inf.puc-rio.br>

Cloud Futures 2012
Berkeley, California
May 2012

McCloud
Service Framework

Agenda

- Introducing you to **McCloud** Service Framework, *the easiest way to develop Monte Carlo simulations in the cloud!*
- Demonstrate **two different** implementations with **McCloud**;
- One in **mathematical** filed with simulations written in **C#;**
- And the other, in **mechanical engineering** area in **Matlab technology**.

McCloud
Service Framework

Monte Carlo

- **MC** is a statistical method to **approximate solutions** of problems;
- It is very useful in a wide range of fields;
- In reality **MC** simulations work out an experiment several times using **random numbers** as input to describe the statistical behavior of a problem;
- The **higher the number of samples** on **MC**, **better is the approximation**;
- Subsequently, **MC** has a large demand on **computational resources**, but on the other hand, it is **easy to parallelize** samples;
- Which makes it an excellent candidate to **go to the cloud**.

Service Framework

We proposed a framework to develop simulation services

- **Why a Framework?**

⇨ Because each problem is particular in its own way. Given that our aim is to allow you to easily and quickly implement the simulation without cloud concerns.

- **Why a Service?**

⇨ Because we want Monte Carlo simulation alone to go to the cloud with minimum changes in your application.

McCloud
Service Framework

Conceptual Architecture

This solution has been structured in three layers

Application

Service Client which can be in any Technology

Software as a Service

Monte Carlo Simulation Service implemented with McCloud

Platform as a Service

Cloud platform with all you need in your simulation
It is available in a friendly web page *(complexity are hidden)*

Framework Workflow

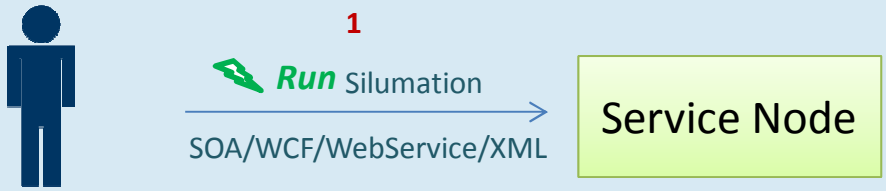
In this demonstration...

The framework methods are in green
They are available to framework clients.

The framework hotspots are in orange
They allow the developers to extend the framework.

McCloud
Service Framework

Framework Workflow



Client Application

1. Let´s imagine an application requesting a simulation to proposed framework

Method
Hotspot

McCloud
Service Framework

Framework Workflow

Run Silumation

SOA/WCF/WebService/XML

Service Node

Test 2

Optimization / Startup 3

Client Application

2. The arguments of this simulation are tested according to the "test" hotspot

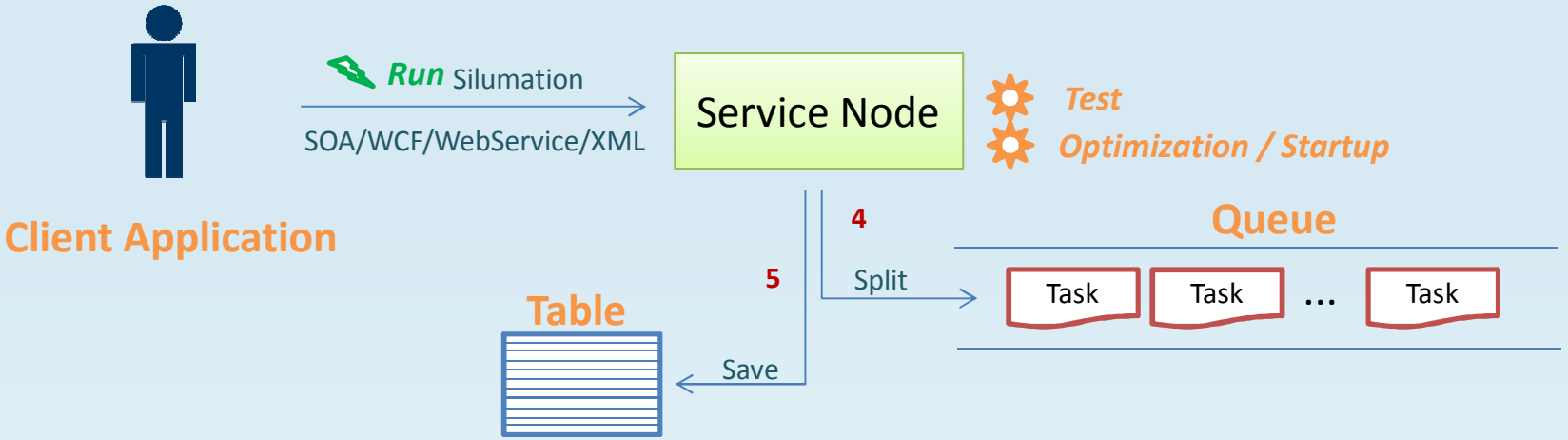
3. And we estimated and got an optimal configuration to execute the simulation according to the "optimization" hotspot, possible starting new Azure worker nodes, running the "startup" hotspot to configuration each node

Method

Hotspot

McCloud
Service Framework

Framework Workflow



4. The simulation has been split in tasks according to an ideal number of tasks estimated. The tasks are saved in the queue

5. The arguments of this simulation are saved onto the table

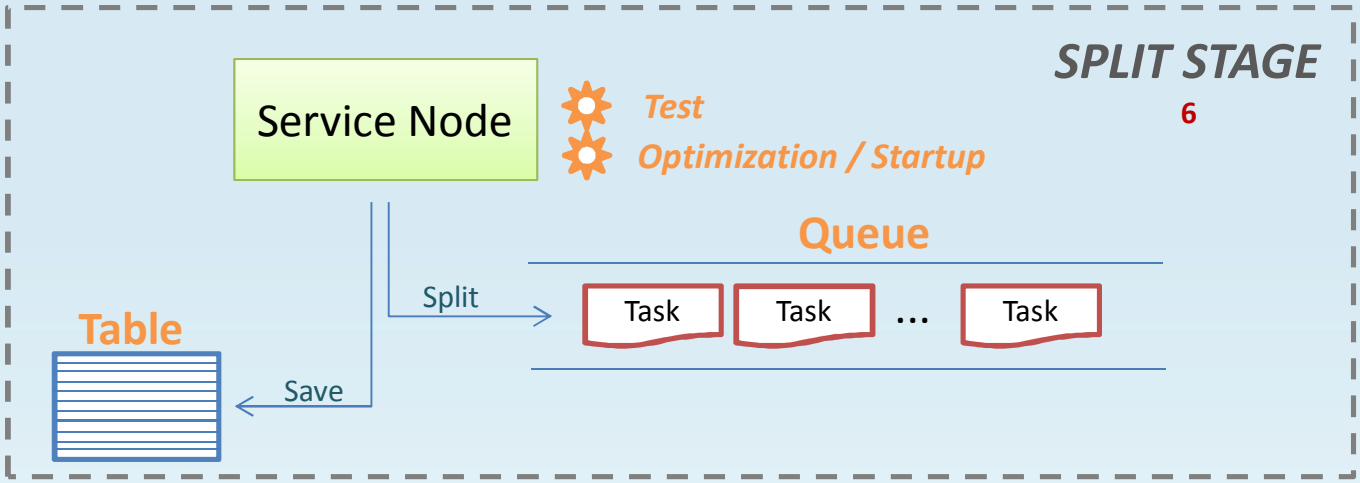
Method
Hotspot

McCloud
Service Framework

Framework Workflow

Key 7

Client Application



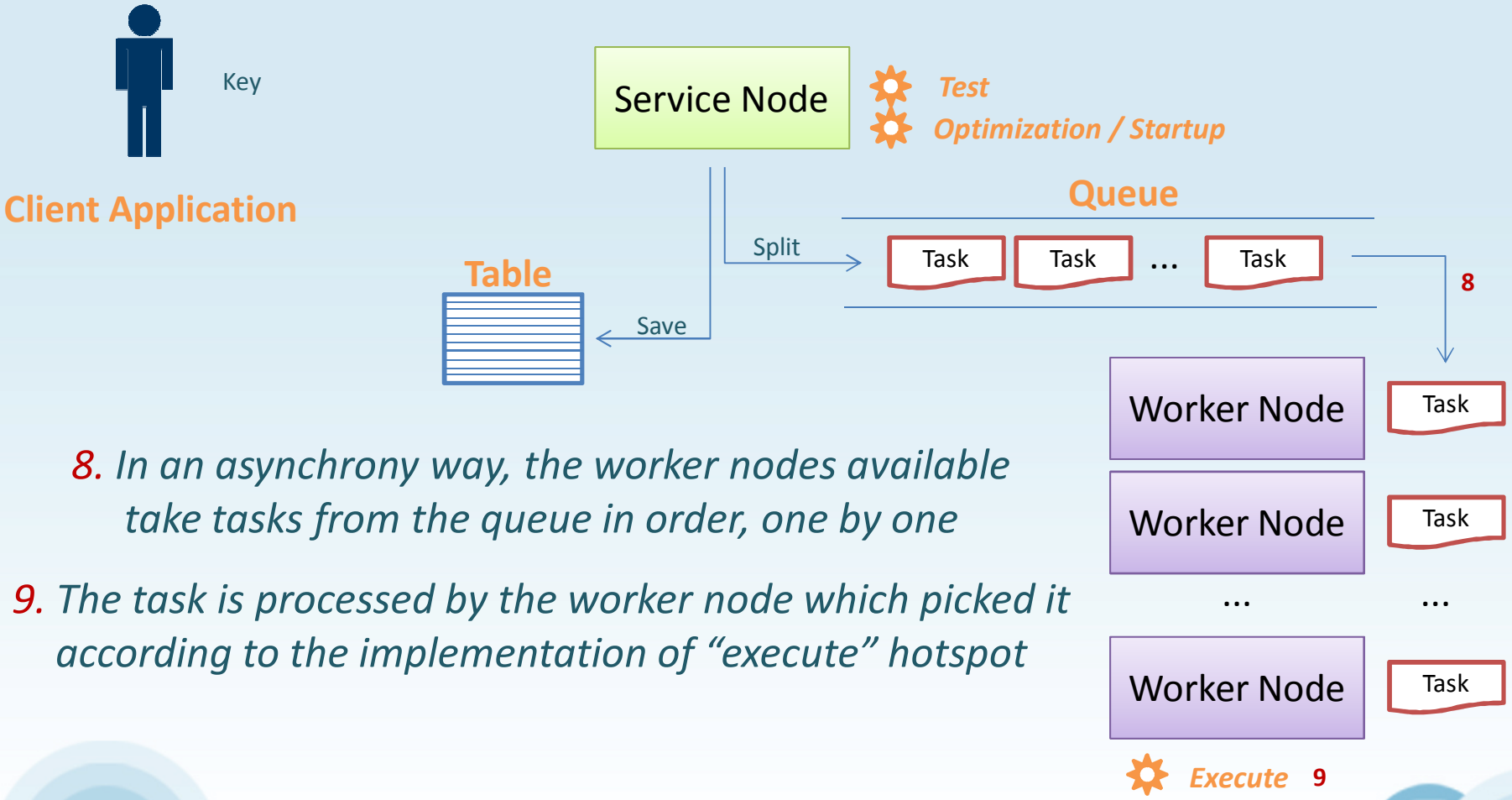
*6. This part of workflow we called **SPLIT STAGE***

7. In the end of stage the client receive a key to identify this simulation

Method
Hotspot

McCloud
Service Framework

Framework Workflow



8. In an asynchrony way, the worker nodes available take tasks from the queue in order, one by one

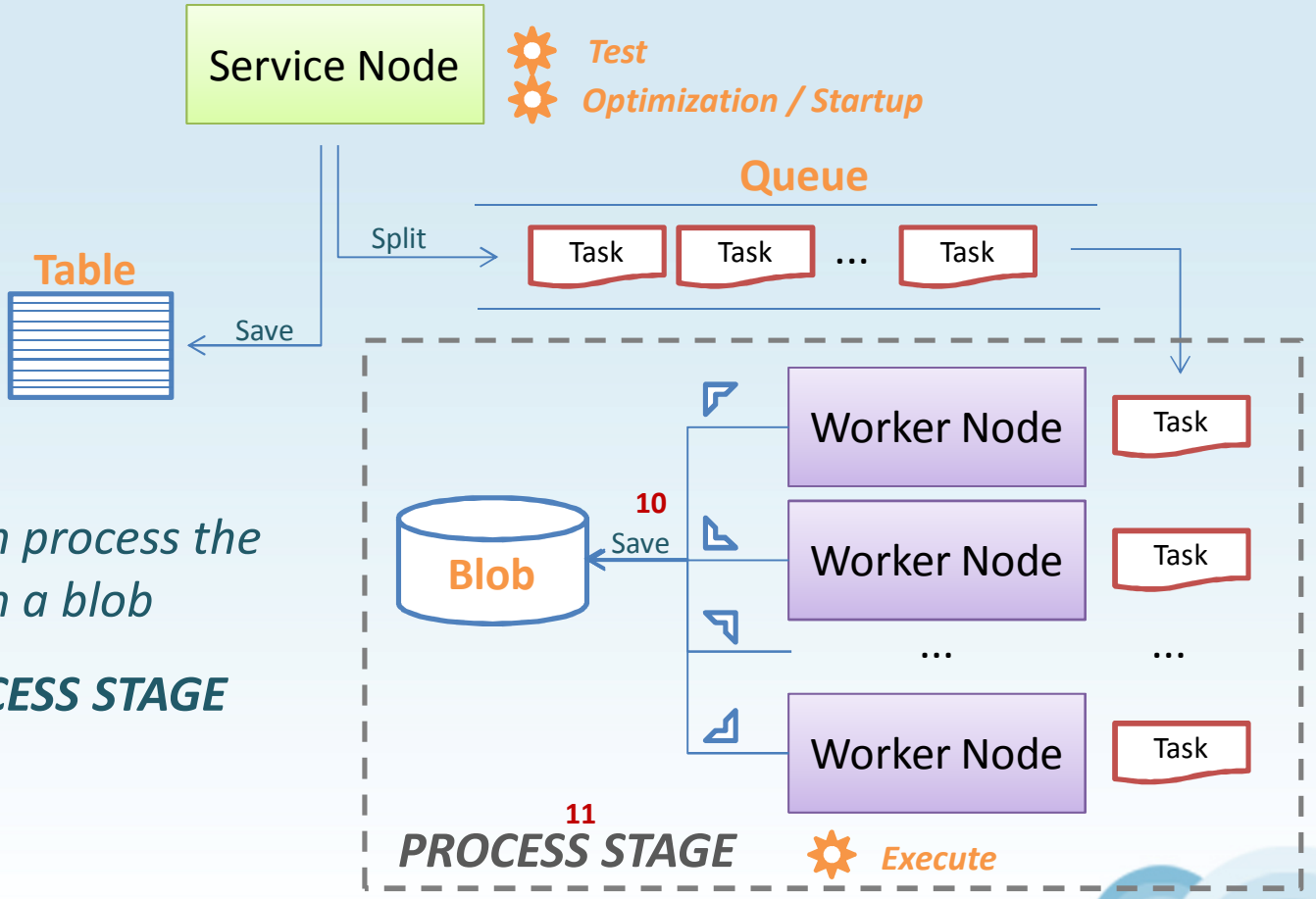
9. The task is processed by the worker node which picked it according to the implementation of "execute" hotspot

McCloud
Service Framework

Framework Workflow

Key

Client Application

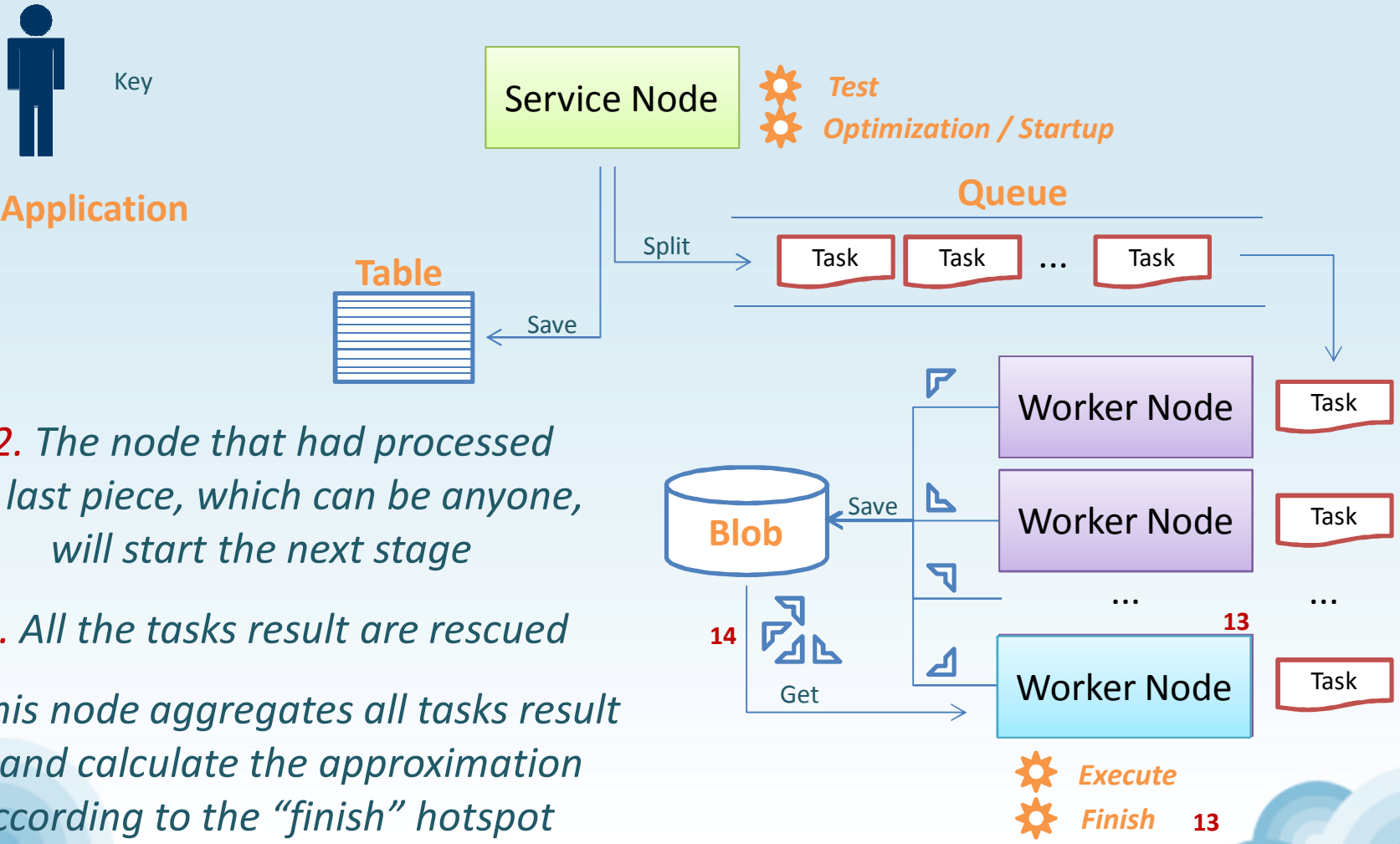


10. In the end of each process the result is saved in a blob

*11. This is the **PROCESS STAGE***

McCloud
Service Framework

Framework Workflow



12. The node that had processed the last piece, which can be anyone, will start the next stage

13. All the tasks result are rescued

14. This node aggregates all tasks result and calculate the approximation according to the "finish" hotspot

McCloud
Service Framework

Framework Workflow

15. The result of approximation is saved in blob and the simulation status is updated on the table

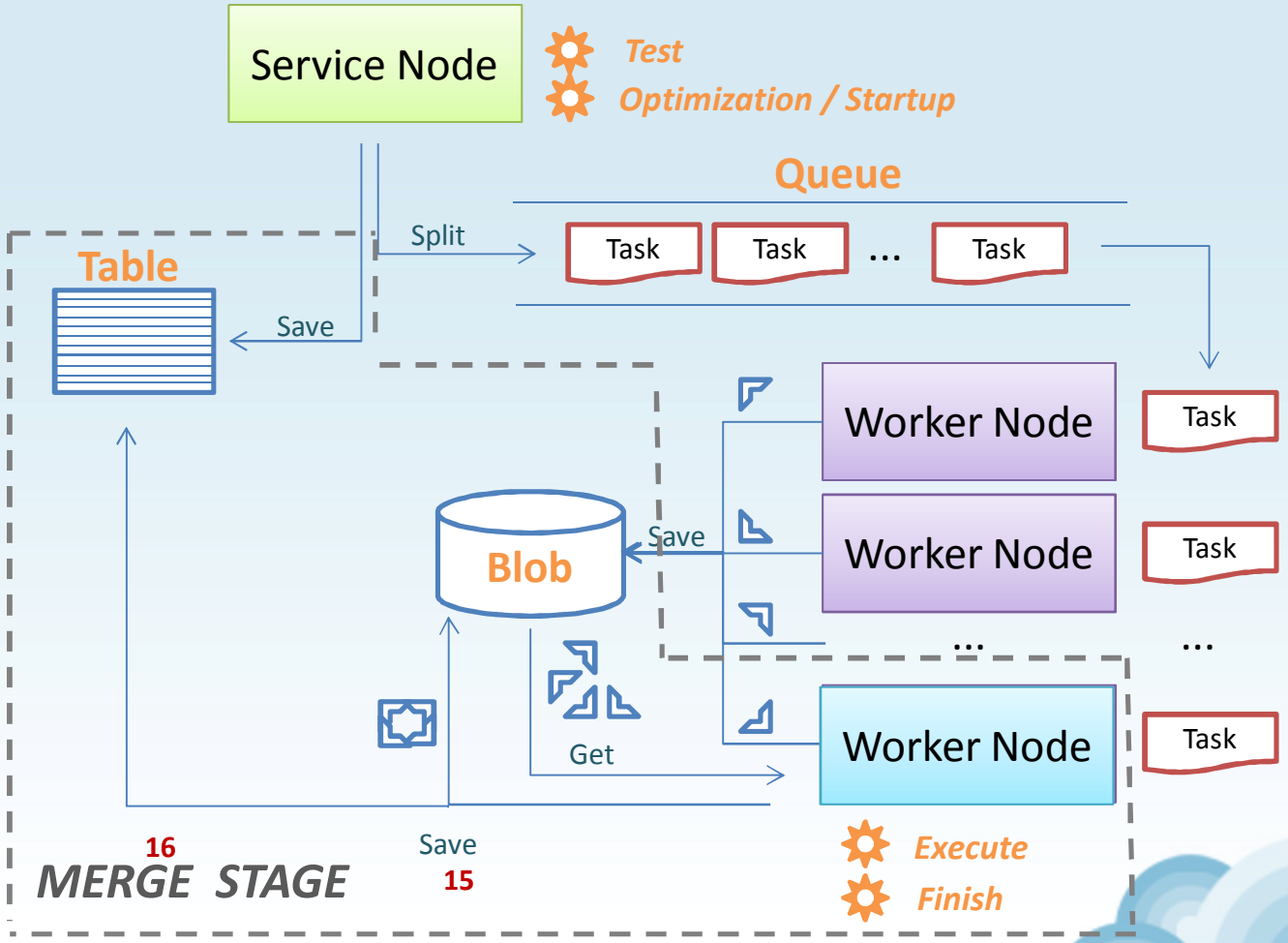
Key

Client Application

*16. This is the **MERGE STAGE**, the last one.*

Method

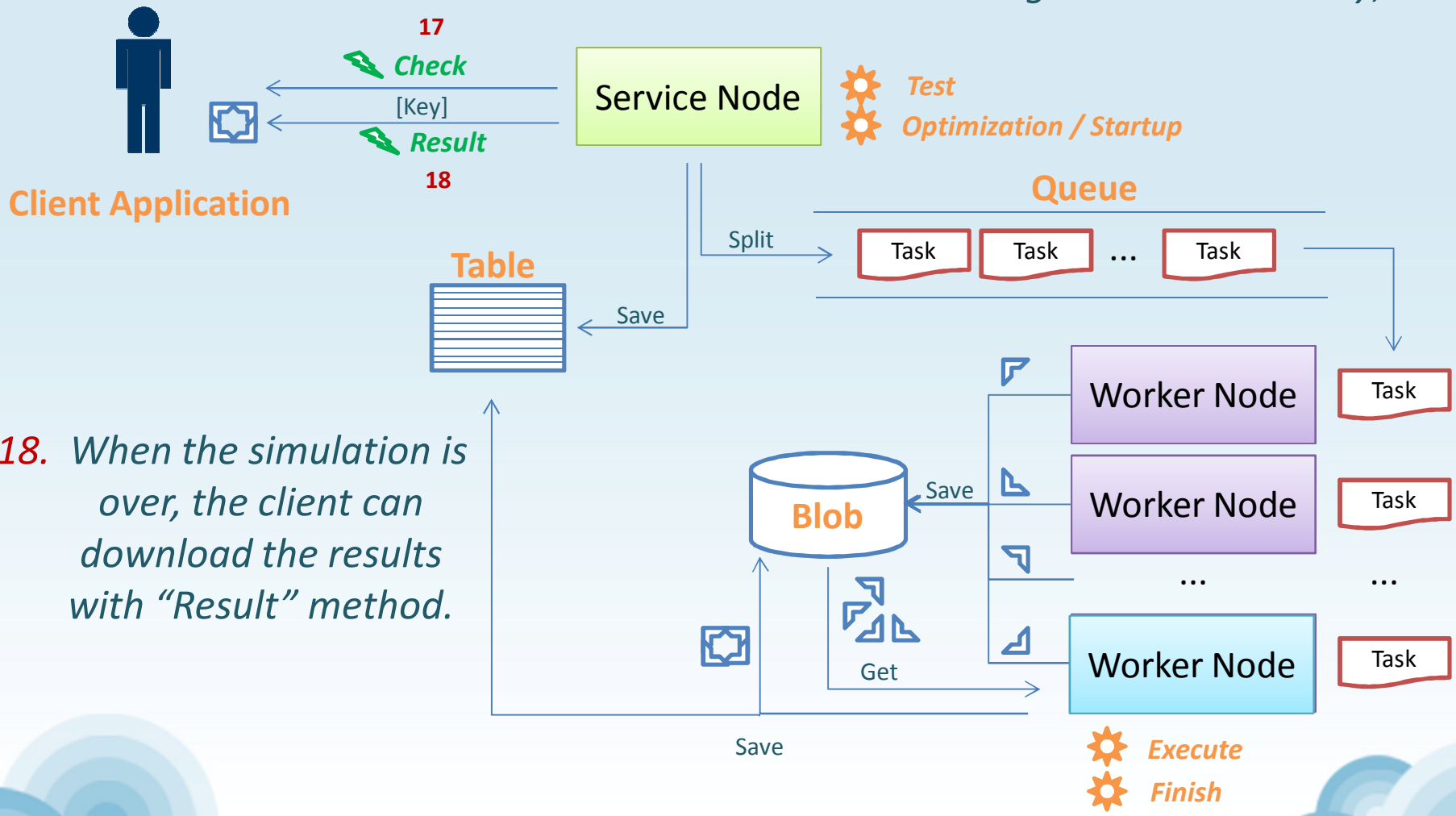
Hotspot



McCloud
Service Framework

Framework Workflow

17. At any time the client can check the status of simulation with "Check" method using the simulation key;



18. When the simulation is over, the client can download the results with "Result" method.

McCloud
Service Framework

Framework Methods

The three methods available in the framework are

```
/// <summary>
/// Runs this simulation in the cloud
/// </summary>
/// <param name="n">Total samples you want in this simulation</param>
/// <param name="codein">Code fragment to use in 'execute' hotspot</param>
/// <param name="codeout">Code fragment to use in 'finish' hotspot</param>
/// <param name="npt">Maximum samples by task</param>
/// <returns>One key to identify this simulation</returns>
[OperationContract]
string Run(double n, string codein, string codeout, double npt);
```

```
/// <summary>
/// Checks the status of this simulation
/// </summary>
/// <param name="key">One key to identify one simulation</param>
/// <returns>Status of this simulation</returns>
[OperationContract]
string Check(string key);
```

```
/// <summary>
/// Gets link to download result of this simulation
/// </summary>
/// <param name="key">One key to identify one simulation</param>
/// <returns>Link to download the result</returns>
[OperationContract]
string Result(string key);
```

Framework Hotspots

With this framework you must implement hotspots only and the framework looks after everything else for you

The main framework hotspots are implemented extending the class **McHotspot**.

```
namespace McHotspoot
{
    public interface McHotspotI
    {
        /// <summary>
        /// Generates samples of one task
        /// </summary>
        /// <param name="key">Key genereted on 'Run' method</param>
        /// <param name="n">Total samples of this task difined by framework</param>
        /// <param name="index">Index of this task defined by framework</param>
        /// <param name="codein">Same code fragment received on 'Run' method</param>
        /// <param name="message">Returns message log to framework</param>
        /// <returns>String with task results processed</returns>
        string execute(string key, double n, double index, string codein, out string message);
```

```
        /// <summary>
        /// Calculates the approximation of simulation
        /// </summary>
        /// <param name="key">Key genereted on 'Run' method</param>
        /// <param name="n">Total samples received on 'Run' method</param>
        /// <param name="r">File address with all tasks results</param>
        /// <param name="codein">Same code fragment received on 'Run' method</param>
        /// <param name="codeout">Same code fragment received on 'Run' method</param>
        /// <param name="message">Returns message log to framework</param>
        /// <returns>String with simulation approximation calculated</returns>
        string finish(string key, double n, string r, string codein, string codeout, out string message);
```

McCloud
Service Framework

Framework Hotspots

```
/// <summary>
/// Tests the parameter received on 'Run' method
/// </summary>
/// <param name="key">Key genereted on 'Run' method</param>
/// <param name="n">Total samples received on 'Run' method</param>
/// <param name="codein">Same code fragment received on 'Run' method</param>
/// <param name="codeout">Same code fragment received on 'Run' method</param>
/// <param name="npt">Same maximum samples by task received on 'Run' method</param>
/// <returns>Returns a message if a problem comes up</returns>
string test(string key, double n, string codein, string codeout, double npt);
```

```
/// <summary>
/// Estimates the best framework configuration to run this simulation
/// </summary>
/// <param name="n">Total samples received on 'Run' method</param>
/// <param name="codein">Same code fragment received on 'Run' method</param>
/// <param name="codeout">Same code fragment received on 'Run' method</param>
/// <param name="npt">Same maximum samples by task received on 'Run' method</param>
/// <param name="ninstancesadded">Amount of new worker nodes to initialize</param>
/// <param name="ntasks">Amount of tasks to split this simulation</param>
/// <param name="timeoutInSeconds">Maximum time to wait the execute of task</param>
void optimization(double n, string codein, string codeout, double npt,
    out double ninstancesadded, out double ntasks, out int timeoutInSeconds);
```

Framework Hotspots

The last hotspot, **startup**, is different...

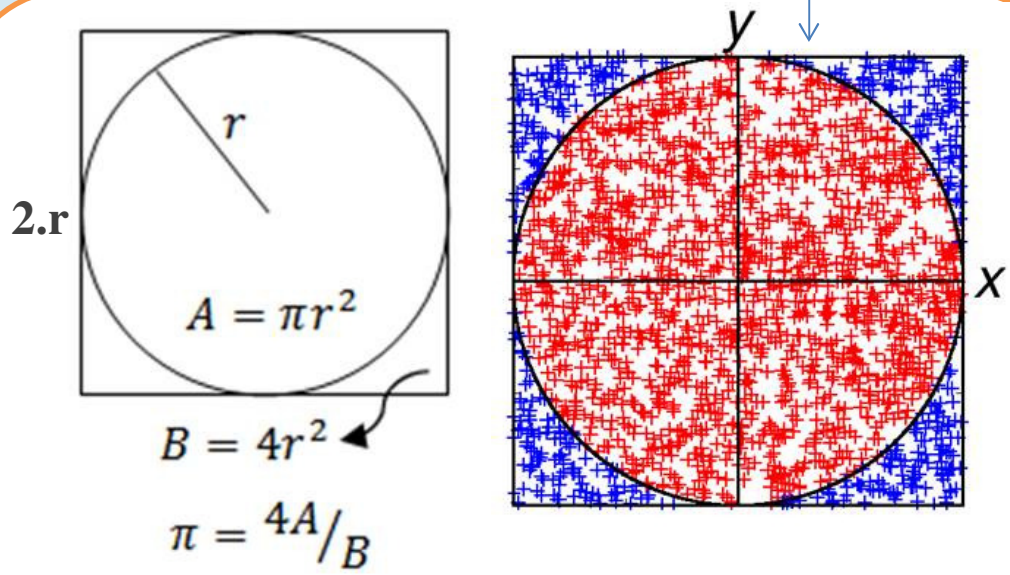
- It needs to be implemented writing the Windows command line file **startup.cmd** and updating files to **onstart** container.
- The framework **runs** this commands and **copies** the files in this container when each node starts.
- Therefore you can **download** and **install** everything you need to implement the other hotspots supporting **any other technology** in simulations!

McCloud
Service Framework

Classic Example

The approximation of π number with Monte Carlo

It´s also easy to see that you can approximate the square and circle area generating many random points inside that.



Consequentially, π can be approximated by:

$$\frac{4 \times \text{Total of red points}}{\text{Total points generated}}$$

It´s easy to notice that π can be represented by a division of circle area by square area, if one is exactly inside the other.

McCloud
Service Framework

Source Code Comparison

*With McCloud we implemented a service to run a C# textual code received in **codein** and **codeout** of **Run** method*

Traditional Algorithm

```
public decimal traditionalAlgorithm(double n)
{
    // Initializes System.Random class, using the specified seed value
    Random a = new Random(1982);
    int min = 0; int max = 1; double countYes = 0;

    // Generates n samples of points
    for (double i = 0; i < n; i++)
    {
        // Generates randon coordinates (x-y) of one point
        double x = min + (a.NextDouble() * (max - min));
        double y = min + (a.NextDouble() * (max - min));

        // Increments the counter if the point inside the circle
        if (Math.Sqrt(Math.Pow(x - 1, 2) + Math.Pow(y - 1, 2)) < 1)
            countYes++;
    }

    // Calculates the approximation
    return (decimal)4.0 * (decimal)countYes / (decimal)n;
}
```

We use Mono CSharp, a free compiler runtime of C#, to run this codes in hotspots.

Bear in mind that you must control the seed!

codein

```
Random a = new Random((int)(1982 + n * index * 2));
int min = 0; int max = 1; double countYes = 0;
for (double i = 0; i < n; i++)
{
        double x = min + (a.NextDouble() * (max - min));
        double y = min + (a.NextDouble() * (max - min));
        if (Math.Sqrt(Math.Pow(x - 1, 2) + Math.Pow(y - 1, 2)) < 1)
                countYes++;
}
string r = countYes.ToString() + ";";
r;
```

codeout

```
// Reads a file with all task results (counter)
FileStream fileStream = new FileStream(r, FileMode.Open);
StreamReader reader = new StreamReader(fileStream);
string content = reader.ReadToEnd();
fileStream.Close();

// Garthers the results (points counter)
string[] countYesTask = content.Split(';');
double countYes = 0;
for (int i = 0; i < (countYesTask.Length-1); i++)
{
        countYes = countYes + double.Parse(countYesTask[i]);
}

// Calculates the approximation
decimal pi = ((decimal)4.0 * (decimal)countYes / (decimal)n);
pi.ToString();
```

We have done minimal changes to the code!

McCloud
Service Framework

Performance Comparison

Amount of Points	Decimal Precision	Duration in 1 Computer	Worker Nodes	Duration McCloud	USD$ McCloud
100	1	0,016 s.	16	10,26 s.	2,19
1.000	1	0,109 s.	16	5,23 s.	2,19
10.000	2	0,375 s.	16	18,59 s.	2,19
100.000	3	0,641 s.	16	13,75 s.	2,19
1.000.000	3	1,719 s.	16	8,07 s.	2,19
10.000.000	3	11,531 s.	19	13,51 s.	2,55
100.000.000	3	109,438 s.	19	13,08 s.	2,55
1.000.000.000	4	20,57 min.	19	36,72 s.	2,55
10.000.000.000	5	2,74 hours	19	3,06 min.	2,55
100.000.000.000	5	1,14 days	19	28,46 min.	2,55
			99	5,71 min.	12,15
1.000.000.000.000	5	11,2 days	99	54,64 min.	12,15

Working with small amount of points the McCloud isn´t a good solution.

But, if you want a better precision, McCloud speedup results with insignificant costs

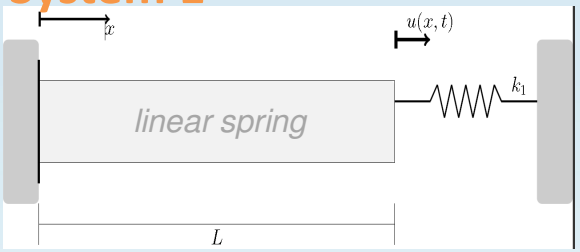
300 speedup

McCloud
Service Framework

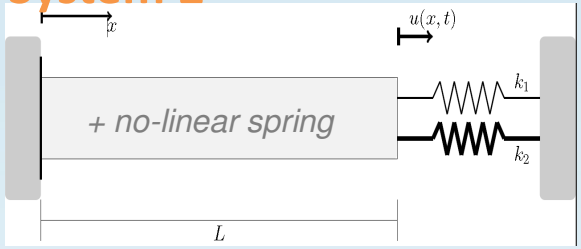
Case Study

We apply the framework in a real problem of Mechanical Engineering, the approximation of bar displacement

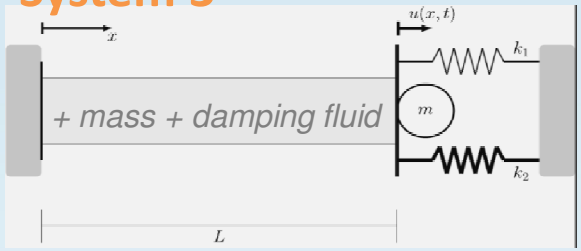
System 1



System 2



System 3



Thanks to PUC-Rio Mechanical Department.
D.Sc. Rubens Sampaio and M.Sc. Americo Cunha .
They model equations and program this systems in Matlab executable.

McCloud
Service Framework

Implementation

Contrasting π example, in this case we can´t run this executable with many samples, because MatLab do an overflow memory.

To solve this, we split it in two pieces, one to generate samples and the other to aggregate samples and calculate the approximation.
Similar to what we did in π with codein/codeout.
Therefore, we can run more samples...

*With **McCloud** we implement a service to run MATLAB executables uploaded in **onstart** container.*

*Besides, on **startup.cmd** we download and install the Matlab Compiler Runtime in all nodes to support this technology in Azure.*

McCloud
Service Framework

Performance

CASE STUDY PERFORMANCE														
			Configuration			Time w/ McCloud (minutes)				Blob		Price	Speedup	
N	System	Platform	WR	Tasks	T/W	Split	Process	Merge	Total	Inside	Output	USD$	T in 1 CPU	x
256	1	Standalone	-	-	-	0,00	2,13	0,05	**2,17**	882KB	879KB	-	-	-
1.024	1	Standalone	-	-	-	0,00	7,94	0,15	**8,09**	3,5MB	879KB	-	-	-
262.144	1	Azure	64	1024	16	0,34	40,06	8,06	**48,47**	882MB	879KB	**7,950**	2.225	46
256	2	Standalone	-	-	-	0,00	11,72	0,04	**11,76**	882KB	879KB	-	-	-
1.024	2	Standalone	-	-	-	0,00	45,73	0,17	**45,90**	3,5MB	879KB	-	-	-
262.144	2	Azure	64	1024	16	0,34	191,03	7,96	**199,33**	882MB	879KB	**31,350**	12.047	60
256	3	Standalone	-	-	-	0,00	10,96	0,05	**11,01**	1,3MB	1,4MB	-	-	-
1.024	3	Standalone	-	-	-	0,00	44,23	0,16	**44,40**	5,2MB	1,4MB	-	-	-
262.144	3	Azure	64	1024	16	1,50	189,62	28,27	**219,38**	1,3GB	1,4MB	**31,350**	11.273	51

1. With 64 nodes we see a great speedup in all system with low cost;

2. I´d like to stress the researchers have never succeed in executing more 1.024 samples (we performed 262.144);

3. As pointed out on this case we have big-data inside the cloud but small outside data transfer.

McCloud
Service Framework

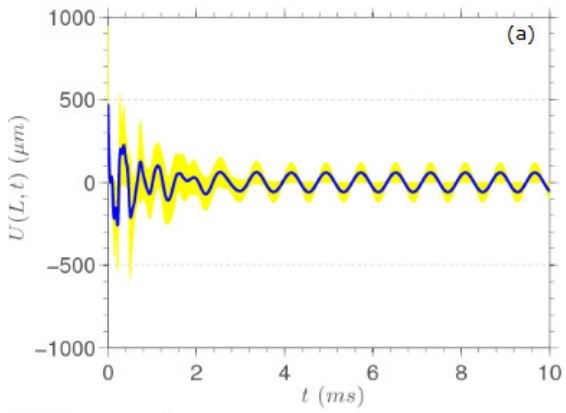
Results

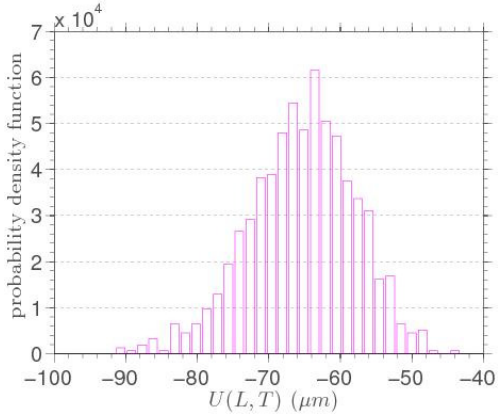
Graphics of System 3 with 1.024 (left) and 262.144 (right) samples

The yellow region on right, with more samples, fits better the mean in blue. It represents the more precision of standard deviation.

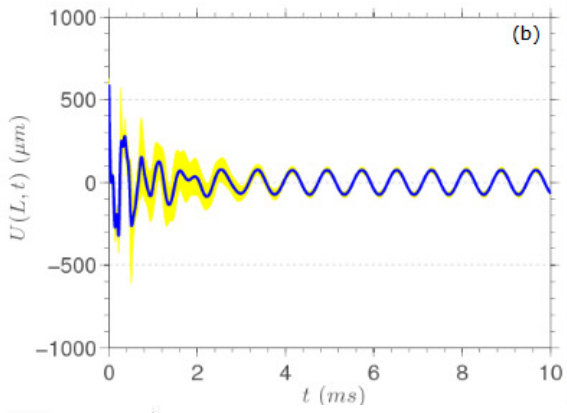
Also, the graphic on the right with more density, better represents the statistical behavior of the problem.

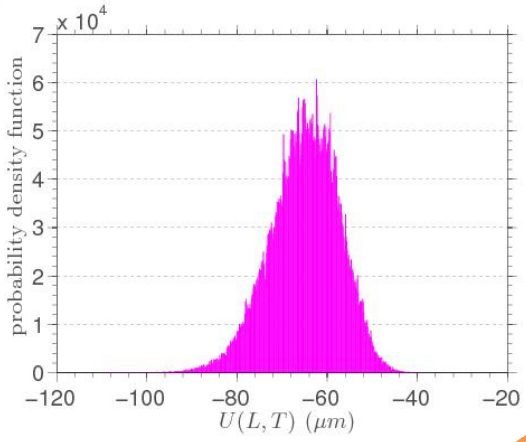
1.024





262.144





McCloud
Service Framework

Conclusion

McCloud allow scientists to **scale up** their experiments in the cloud, with **minimal changes** to the code they are used to, with very **low cost**.

http://mccloud.codeplex.com

McCloud
Service Framework

Hotspots (C# Textual Code)

CSharp.cs | MatLab.cs | Startup.cmd

McHotspoot.CSharp — test(string key, double n, string codein, string codeout, double npt)

```
public class CSharp : McHotspotI
{

    public string execute(string key, double n, double index, string codein, out string message)
    {
        Mono.CSharp.Evaluator.Run("using System;");
        Mono.CSharp.Evaluator.Run("double index = " + index + ";");
        Mono.CSharp.Evaluator.Run("double n = " + n + ";");
        string r = (string)Mono.CSharp.Evaluator.Evaluate(codein.TrimEnd());
        message = "Code: " + codein + "\r\n" + "Result: " + r;
        return r;
    }

    public string finish(string key, double n, string r, string codein, string codeout, out string message)
    {
        Mono.CSharp.Evaluator.Run("using System;");
        Mono.CSharp.Evaluator.Run("using System.Text;");
        Mono.CSharp.Evaluator.Run("using System.IO;");
        Mono.CSharp.Evaluator.Run("double n = " + n.ToString() + ";");
        Mono.CSharp.Evaluator.Run("string r = @" + "\"" + r + "\"" + ";");
        string m = (string)Mono.CSharp.Evaluator.Evaluate(codeout.TrimEnd());
        message = "Code: " + codeout + "\r\n" + "Result: " + m;
        return m;
    }
```

McCloud
Service Framework

Hotspots (Matlab)

CSharp.cs | MatLab.cs | Startup.cmd

McHotspoot.MatLab | optimization(double n, string codein, string codeout, double npt, out double ninstar

```
public class MatLab : McHotspotI
{
    public string execute(string key, double n, double index, string codein, out string message)
    {
        string filename = "process";
        string filesRoot = RoleEnvironment.GetLocalResource("McCloudStorage").RootPath;
        string matlab1 = Path.Combine(filesRoot, filename + ".exe");
        string output1 = "P_" + key + index + ".csv";
        exec(matlab1, new string[] {n.ToString(), index.ToString(), codein, output1}, out message);
        FileStream fileStream = new FileStream(output1, FileMode.Open);
        StreamReader reader = new StreamReader(fileStream);
        string r = reader.ReadToEnd();
        fileStream.Close();
        return r;

    }

    public string finish(string key, double n, string r, string codein, string codeout, out string message)
    {
        string filename = "merge";
        string filesRoot = RoleEnvironment.GetLocalResource("McCloudStorage").RootPath;
        string matlab2 = Path.Combine(filesRoot, filename + ".exe");
        string output1 = r;
        string output2 = "M_" + key + ".csv";
        exec(matlab2, new string[] { n.ToString(), codeout, output1, output2 }, out message);
        string m = "";
        FileStream fileStream2 = new FileStream(output2, FileMode.OpenOrCreate);
        StreamReader reader = new StreamReader(fileStream2);
        m = reader.ReadToEnd();
        fileStream2.Close();
        return m;
    }
```

McCloud
Service Framework

Hotspots (Matlab)

CSharp.cs | MatLab.cs | Startup.cmd

```
:MATLAB
REG QUERY %regpath% /v vcredist_x86
IF errorlevel 1 (
    BootStrapper.exe -get %MyBlobStorageEndpoint%/startup/vcredist_x86.exe -lr C:\mccloud\ -run C:\mccloud\vcredist_x86.exe -args /w /s /v/qn -block
    REG ADD %regpath% /v vcredist_x86 /t REG_SZ /d 1 /f
)

REG QUERY %regpath% /v MCRInstaller
IF errorlevel 1 (
 BootStrapper.exe -get %MyBlobStorageEndpoint%/startup/MCRInstaller.exe -lr C:\mccloud\ -block

 net start "task scheduler"
 net user McCloud m4c2d4h49 /add
 net localgroup Administrators McCloud /add

 schtasks /Create /SC ONCE /ST 00:00 /SD 01/01/2100 /TN task_MCRInstaller /TR "C:\mccloud\MCRInstaller.exe /w /s /v/qn" /F /RU McCloud /RP m4c2d4h49 /RL HIGHEST
 schtasks /Run /TN task_MCRInstaller

 REG ADD %regpath% /v MCRInstaller /t REG_SZ /d 1 /f

 shutdown -r -t 390
)
```

McCloud
Service Framework

Matlab Example

```
function process(n, index, codein, output)
    tic
    N = str2double(n);
    rng(str2double(codein)+N*2*str2double(index));
    min = 0; max = 1; c = 0;
    for i=1:N
        x1 = min + (rand(1,1) * (max - min));
        x2 = min + (rand(1,1) * (max - min));
        x = sqrt( (x1 - 1)^2 + (x2 - 1)^2 );
        if (x < 1)
            c = c + 1;
        end
    end
    fid=fopen(output,'w');
    fprintf(fid,'%u;',c);
    fclose(fid);
    toc
end
```

```
function merge( n, codeout, input, output )
    tic
    N = str2double(n);
    fid1=fopen(input,'r');
    r = fscanf(fid1, '%u;');
    sum = 0;
    [lines, cols] = size(r);
    for i=1:lines
        sum = sum + r(i,1);
    end
    estPi = 4 * sum / N;
    fid2=fopen(output,'w');
    fprintf(fid2,'%f',estPi);
    fclose(fid2);
    toc
end
```

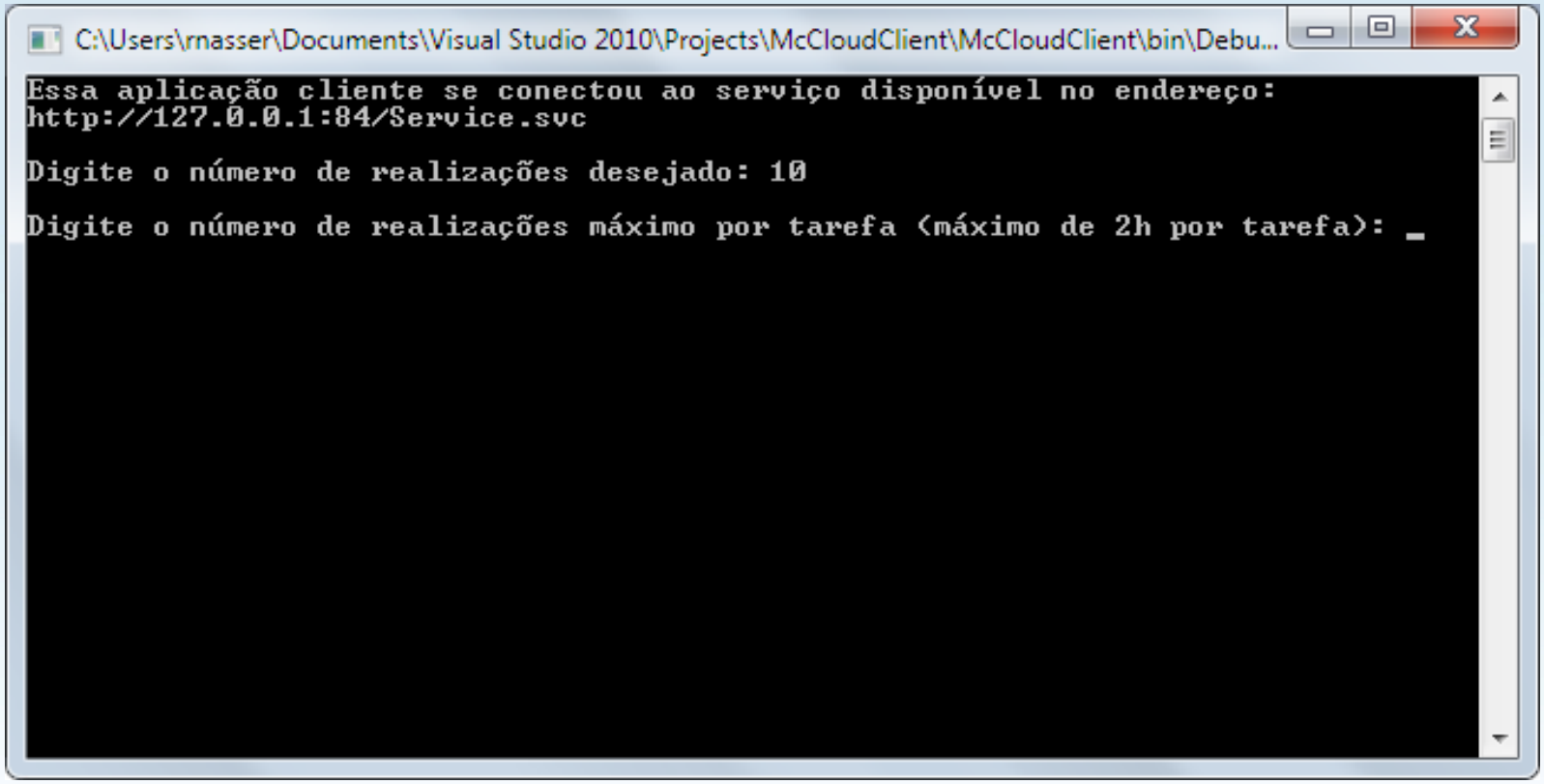
McCloud
Service Framework

PHP Client Example

```php
<?php
set_time_limit (0);
$wsdl = 'http://maccloudcsharp.cloudapp.net/Service.svc?wsdl';
$mcc = new SoapClient($wsdl);
$obj->n = $_GET['n'];
$obj->codein = '...';
$obj->codeout = '...';
$result = $mcc->Run($obj);
$key = $result->RunResult;
echo $key
?>
```

McCloud
Service Framework

C# Client Example



Thank you!

http://mccloud.codeplex.com