Intensive Care Cloud (ICCloud)
Intensive Care Cloud - ICCloud

- Led by the Internet Computing Lab / University of Cyprus (http://www.grid.ucy.ac.cy)

- **Problem Target**
  - ICU Patient monitor at any time any place.
  - Identification of similar clinical episodes in a knowledge database.
  - Protect and Secure Private Data.

- **Objectives**
  - Overcome storage and computational capabilities.
  - Design the parallelization model for data analysis.
  - Create public repositories of non-Private Health Information.
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• **Problem Target**
  – Patient monitor.
  – Identification of similar clinical episodes in a knowledge database.
  – Protect and Secure Private Data.

• **Objectives**
  – Overcome storage and computational capabilities.
  – Design the parallelization model for data analysis.
  – Create two individual data repositories to uphold Private and Non-Private Health Information.
ICCloud
User Community and Benefits

• User Community
  – ICU medical practitioners.
    – using real time processing functionality and data annotation feature.
  – ICU medical trainees and ICU medical researchers
    – using scenario playback and post analysis services.

• Why the “Cloud”?
  – Take advantage of simple storage schemas (blobs, tables, local storage) (or in the future design more complex data associations via SQL server)
  – Job submission without long queue delays.
  – Deliver a Software as a Service solution (second phase of development) to reduce end-user application management overhead (installations, configuration, customization, etc).
Venus-C Architecture

• Why Venus – C?
  – VENUS-C aims to develop, test and deploy an industry-quality, highly-scalable and flexible Cloud infrastructure to empower researchers through the easy deployment of end-user services.
  – Enables the usage of multidisciplinary cloud infrastructures.
  – Hides deployment details.
Venus – C Partners

Project Management
- Engineering Informatica

Resource Providers
- Microsoft Research
- Barcelona Supercomputing Center
- KTH

Technical Management
- Microsoft Innovation Center Europe
- Microsoft Innovation Center - Greece
- Universidad Politecnica de Valencia

User Scenarios
- Centre for Computational and Systems Biology
- Venice Gateway for Science and Technology
- National Research Council of Italy
VENUS-C CLOUD INFRASTRUCTURES

OpenNubula
- KTH, 16 computing nodes
- ENGINEERING, 4 servers

Emotive
- 90,000 CPU hours per year and 600GB of storage

Supercomputer (BSC)
- 134 PowerPC CPUs and 9.3 TB

MS AZURE (Microsoft)
- 8,000,000 CPU hours and 10,000 GB of storage per year
VENUS-C has also provided seed funds for 15 pilots with applications spanning biology, bioinformatics, chemistry, earth sciences, maritime surveillance, mathematics, medicine and healthcare, physics and social media.

**Basic Sciences**
- CAD
- CALCIUM
- CLOUD-QUAKE
- PARSEC
- CloudERT
- cTQm

**Bio Sciences**
- MoDoC
- ScaBIA
- AOLBSD
- Bio-CIRRUS
- Cloud4Trends
- ImPrOV
- ImPrOV
- TARCLOUD
- TRVeC

**Engineering**
• Since ICCloud is a .net application (c#, vb.net) it favorites Microsoft Solutions
• Tables, Blobs and Queues are also supported in other infrastructures and it would be a challenge to see it happening.
• During the first face of development we will be utilizing only the MS Azure Cloud services.

What is a Typical Scenario Venus-C scenario?
Simple Walkthrough

Notifications Listeners (Accounting, Status Change, etc..)

Client code

Pluggable Runtime Environment

Job Management Service

Notification Service

Scaling Service

Runtime Business Logic

Job Details Table

Job Queue

Algorithm

GW Driver

Application Code

VENUS-C Services & SDKs

Existing Components

Application Storage

User's cloud storage

Local storage

Researcher

Virtual multidisciplinary Environments Using Cloud infrastructures
Simple Walkthrough

Client code

Job Management Service

Notification Service

Scaling Service

Pluggable Runtime Environment

Runtime Business Logic

Job Details Table

Job Queue

Algorithm

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(Accounting, Status Change, etc..)

GW Driver

Local storage

Application Storage

User’s cloud storage

Virtual multidisciplinary Environments Using Cloud infrastructures
The functionality of the Generic Worker can be described in six easy steps.

1. Looking for submitted jobs
2. Fetching job details
3. Download application and required files
4. Run application
5. Write back result files

It can be used both for submitting jobs and data management.
• **Web role.** A Windows Azure Web role is used for hosting front-end web applications behind Internet Information Services (IIS).

• **Worker role.** A Worker can run anything but is most commonly used to host background processing behind a web role. Windows Azure Web and Worker roles enable developers to deploy and manage applications services as a whole as opposed to individual Virtual Machines (VMs).

• **Virtual Machine role.** The Windows Azure Virtual Machine (VM) role enables you to deploy a custom Windows Server 2008 R2 (Enterprise or Standard) image to Windows Azure. The VM role runs a virtual hard drive (VHD) image of a Windows Server 2008 R2 virtual machine.
Windows Azure gives you **four** core storage services that are **secure**, **scalable**, and **easy to access** that remain persistent and durable storage in the cloud. **Blobs**, **Tables**, and **Queues** are all available as part of the Windows Azure Storage account, and provide durable storage on the Windows Azure platform. Unlike **local storage**, blobs, tables, and queues are accessible by multiple applications or application instances simultaneously, and represent dedicated storage instead of temporary.
Cloud Storage

All your content stored on Windows Azure is replicated three times

- **Binary Large Object (BLOB)** Service, is currently the simplest way to store text or binary data with Windows Azure.

- **Table Service** is better for large amounts of data that need additional structure, which works exceptionally well with applications that need to work with data in a very detailed manner via queries.

- **Queue Service** for reliable, persistent messaging between Web and Worker role instances.
Cloud Storage – BLOB

All your content stored on Windows Azure is **replicated three times**

- ***_App** = application files and executable package
- ***_Desc** = application description
Cloud Storage – Tables

All your content stored on Windows Azure is **replicated three times**

- Unique name inside a storage account
- Entities contain at least a Partition and Row Key. Other columns can vary even in the same table.
• **Windows Azure Connect.** Windows Azure Connect provides a simple and easy-to-manage mechanism to setup IP-based network connectivity between on-premises and Windows Azure resources. This capability makes it easier for an organization to migrate their existing applications to the cloud by enabling direct IP-based network connectivity with their existing on-premises infrastructure. Developers can setup direct connectivity to their cloud-hosted virtual machines, enabling remote administration and troubleshooting using the same tools that they use for on-premises applications.

• **Windows Azure Traffic Manager.**
  - Windows Azure Traffic Manager is a new feature that allows customers to load balance traffic to multiple hosted services. Developers can choose from three load balancing methods: Performance, Failover, or Round Robin.
  - Traffic Manager will monitor each collection of hosted service on any http or https port. If it detects the service is offline Traffic Manager will send traffic to the next best available service. By using this new feature businesses will see increased reliability, availability and performance in their applications.
ICCloud – Main Goal

- Upload us many patients as possible (create a database using Windows Azure Tables) on Venus-C.
- What kind of patients?
  - Surrogate patients.
- Where the data come from?
  - Patient’s vital signs are based on 12 record sets captured in real ICU setups.
- What kind of Data to upload on public Cloud?
  - Non-Protected Health Information

Simple Use Case

- Develop a scenario where a Patient is hospitalized.
- Monitor Patient.
- Observe and find similar behaviours among the patient database.
  - fire-up jobs based on a map reduce model.

ICCloud (PC based and/or SaaS)

Monitor

Analysis
ICCloud – PHI

PUBLIC LAW 104-191 AUG. 21, 1996 HEALTH INSURANCE PORTABILITY AND ACCOUNTABILITY ACT OF 1996
http://aspe.hhs.gov/admnsimp/pl104191.htm

- 1. Names
- 2. All geographical identifiers smaller than a state
- 3. Dates (other than year) directly related to an individual
- 4. Phone numbers
- 5. Fax numbers
- 6. Email addresses
- 7. Social Security numbers
- 8. Medical record numbers
- 9. Health insurance beneficiary numbers
- 10. Account numbers
- 11. Certificate/license numbers
- 12. Vehicle identifiers and serial numbers, including license plate numbers;
- 13. Device identifiers and serial numbers;
- 14. Web Uniform Resource Locators (URLs)
- 15. Internet Protocol (IP) address numbers
- 16. Biometric identifiers, including finger, retinal and voice prints
- 17. Full face photographic images and any comparable images
- 18. Any other unique identifying number, characteristic, or code except the unique code assigned by the investigator to code the data

VITAL SIGNS AND PHYSIOLOGICAL PARAMETERS ARE non-protected health information
Thus they can be uploaded outside hospital premises
ICCloud - Components

Intensive Care
Bedside Controller

- Hospital Management
- Patient Monitor
- Computer-Aided Diagnosis

Venus-C Framework
- Service Interface
- Data Manager
- Elasticity Manager

Venus-C Infrastructure
- Virtual Hospital
- Virtual patient

Configure/Execute Scenario

Monitor Patient

Intensive Care Cloud

Patient Envelop

Data Mining/Signal Processing
Hospital Management. Used to create the schema of Virtual Hospitals and Patients. Configuration views will provide the tools to start and stop the simulation. The objective is to develop a stand alone application (second phase).

Patient Monitor. Download vital signs and physiological parameters from Cloud Storage.

Virtual Hospital. Hospital simulation executed in a VM using a Generic Worker (a simple job).

Virtual Patient. Patient simulation executed in a VM using a Generic Worker (a simple job).

Patient Envelop. A group of Azure Tables to store patient physiological parameters and vital signs (currently one table can serve our needs).

Computer-Aided Diagnosis. Use a parallelization technique (like MAP-REDUCE) to reduce processing time. Using the elasticity manager and setting criticality cardinals one could scale up or down the processing power. Research Activities.

Data Analysis (timeseries). Develop a naïve algorithm to serve in the evaluation of the proposed solution. Research Activities
ICCloud – Storage model

Patient Data

- Vital signs, Patient non-Private Health Information

Check In Date/Time
ICCloud – Storage model
Patient List

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<thead>
<tr>
<th>PartitionKey</th>
<th>RowKey</th>
<th>Timestamp</th>
<th>BaseStreamID</th>
<th>Gender</th>
<th>Height</th>
<th>imCU</th>
<th>Weight</th>
<th>YearOfBirth</th>
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Real Stream Information

<table>
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<th>Gender</th>
<th>Height</th>
<th>Weight</th>
<th>Cause</th>
<th>Outcome</th>
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<td>7/11/1942 12:00:00</td>
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<td>95</td>
<td>CARDIAC ARREST</td>
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<td>7/11/1942 12:00:00</td>
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<td>170</td>
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<td>CORONARY ARTERY BYPASS GRAFT</td>
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<td>Male</td>
<td>165</td>
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<td>MULTI-INJURY / SPLENECTOMY</td>
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<td>Male</td>
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<td>Male</td>
<td>185</td>
<td>97</td>
<td>MULTI-INJURY</td>
<td></td>
</tr>
</tbody>
</table>

Additional Info
- Hospital Info
- Doctor
- ...
• Select a vital sign type or group of vital signs and a time period.
• Deploy jobs using generic worker. Each job fetches data from WAT and
• Use Azure Tables to synchronize jobs

Write report
ICCloud – Computation model

• Use global storage to map jobs to patient list.
• Each job processes data until patient list is exhausted.
• Results are stored in separate table (matching method and score varies based on selected algorithm)
• Report completion
• How many jobs???
• What is the flexibility of the system in cases where massive computation is needed exceeding predefined VMs?

Map jobs to patients

Find Match
Report Results
Use results for Diagnosis
How much does it cost to use the resources?

- For the first two years is **free**.

### Storage

<table>
<thead>
<tr>
<th>Storage Commit</th>
<th>Price</th>
<th>Discount of Standard Rate</th>
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</thead>
<tbody>
<tr>
<td>1 - 50 TB / month</td>
<td>$0.11 / GB</td>
<td>10.7%</td>
</tr>
<tr>
<td>51 - 500 TB / month</td>
<td>$0.096 / GB</td>
<td>20%</td>
</tr>
<tr>
<td>501 - 1,000 TB / month</td>
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</tr>
<tr>
<td>1,001 TB - 5 PB / month</td>
<td>$0.083 / GB</td>
<td>29.3%</td>
</tr>
<tr>
<td>Greater than 5 PB / month</td>
<td>Please contact us</td>
<td>Please contact us</td>
</tr>
</tbody>
</table>

- Partition(16 bytes)+ Row(8 bytes)+ TS(4 bytes)+ Dvalue (4 bytes) + PhysioState(8 bytes)+ Svalue (16 bytes)+ Toffset (4 bytes)+ TypeofDouble (1 byte) = 61 Bytes per row
- 20~25 monitoring parameters
- 5 snapshots per minute => ~1MByte/per day per patient
- An average ICU 700~1000 per year

- Or
- For the first year the cost is 470 USD to store all physiological parameters.
- And 1000 Euros the cost for the Transactions (upload data 0,01 USD / 10000 transactions)
- What about vital signs
  - ECG ? => 1 Gbyte / day (512 Hz 5 lead)
  - EEG ? => 3GByte / day (200 Hz sampling rate 25 electrodes)
How much does it cost to use the resources?

<table>
<thead>
<tr>
<th>Virtual Machine Size</th>
<th>CPU Cores</th>
<th>Memory</th>
<th>Cost Per Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra Small</td>
<td>Shared</td>
<td>768 MB</td>
<td>$0.02</td>
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<tr>
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<td>$0.12</td>
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<tr>
<td>Medium</td>
<td>2</td>
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<td>$0.24</td>
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<tr>
<td>Large</td>
<td>4</td>
<td>7 GB</td>
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<tr>
<td>Extra Large</td>
<td>8</td>
<td>14 GB</td>
<td>$0.96</td>
</tr>
</tbody>
</table>

• 1 Small VM processing hour costs 1 hour.

• => An average physiological parameter set consists of 20000 values. Using small VMs processing takes aprox. Less than 10 seconds for each parameter (load data from table and process).
• We monitor at least 25 parameters
• Current database consists of 500 patients thus will need 25*500 = ~30 hours
  ⇒ 4 USD per analysis (not so expensive).
  ⇒ Using 15 small VMs (allocation for the needs of our Pilot) we could get the results in less than 2 hours.
  ⇒ Using more VMs and selecting more effective algorithms we could achieve “Near real time diagnosis”
ICCloud: What next?

- **Upload real data in real time**
  - If we overcome law issues, ICBC (bedside controller) could upload non-PHI on Cloud Storage in real time.

- **Join forces with other efforts**
  - MIMIC II database from MIT

- **Develop the security model**
  - Who is Who
  - What data can get access to
  - What access rights users have (view, write, modify, execute, ...)

- **Use a programming schema that no preconfigured analysis method will be needed.**
  - Users should only be asked to select or provide the data analysis method

- **Evaluate Venus-C elasticity manager**
  - This could save time and money
Thank you
ICCloud: Select physiological parameters to monitor
ICCloud: Monitor Patient state