# Grid Programming (1)

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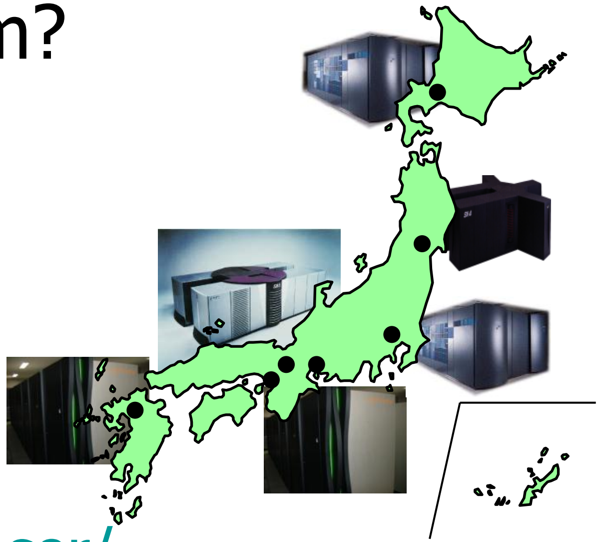
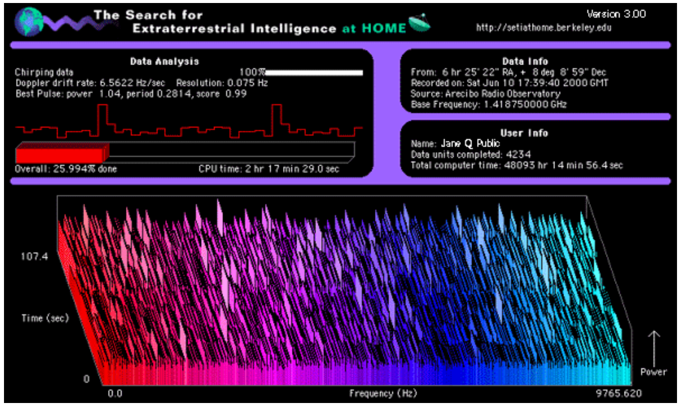
# Overview

- **Grid Computing**
  - Computational Grid
  - Data Grid
  - Access Grid
- **Grid Technology**
  - Security - Single Sign On
  - Information Service
  - Data management
  - Widearea Data Transfer
  - Resource Management
- **Open Grid Forum (OGF)**
  - http://www.ogf.org/

# What is Grid Technology?

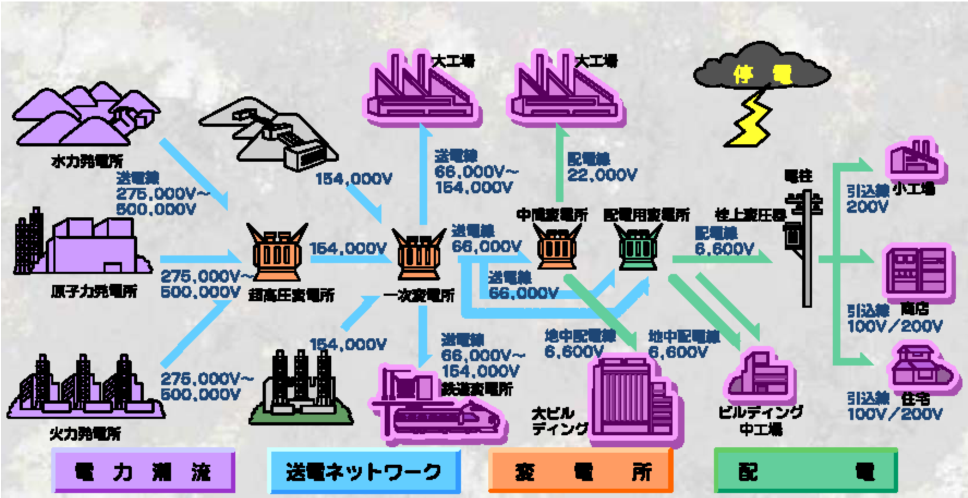
- Is it a technology to connect among supercomputers and to share them?
  - http://www.itbl.jp/
- Is it SETI@Home, UD Cancer research project, or Fight AIDS@home?
  - http://setiathome.ssl.berkeley.edu/
  - http://members.ud.com/projects/cancer/
  - http://www.fightaidsathome.org/
- Is it a next generation Internet technology?
  - IPv6, QoS, IPsec, . . .

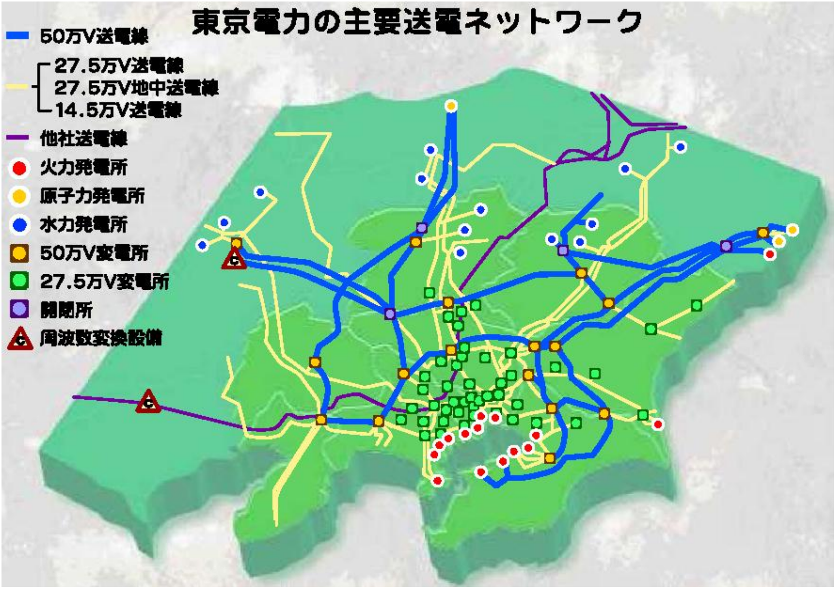




# Grid

- Used after the middle of '90
- From similarity to Electric Power Grids
  - Electric Power Grids provides enough power, using another route in case of trouble.  It is monitored, controlled, and operated.
  - Quite important invention besides power generator, electronic products



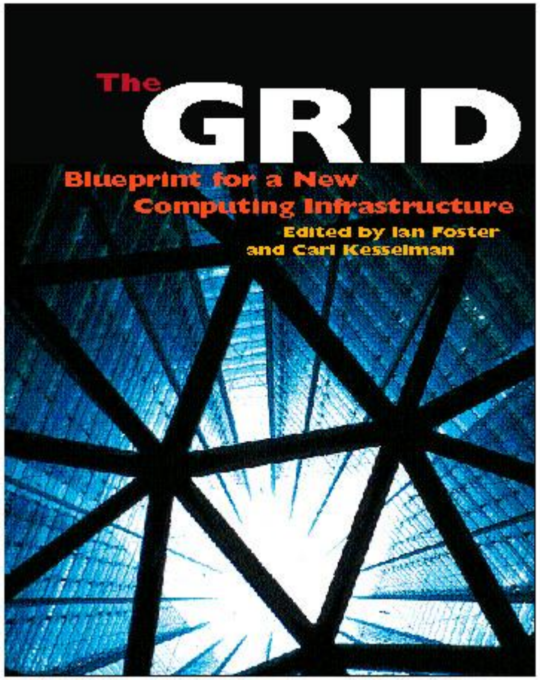




http://www.tepco.co.jp

# Definition of Grid in 1999

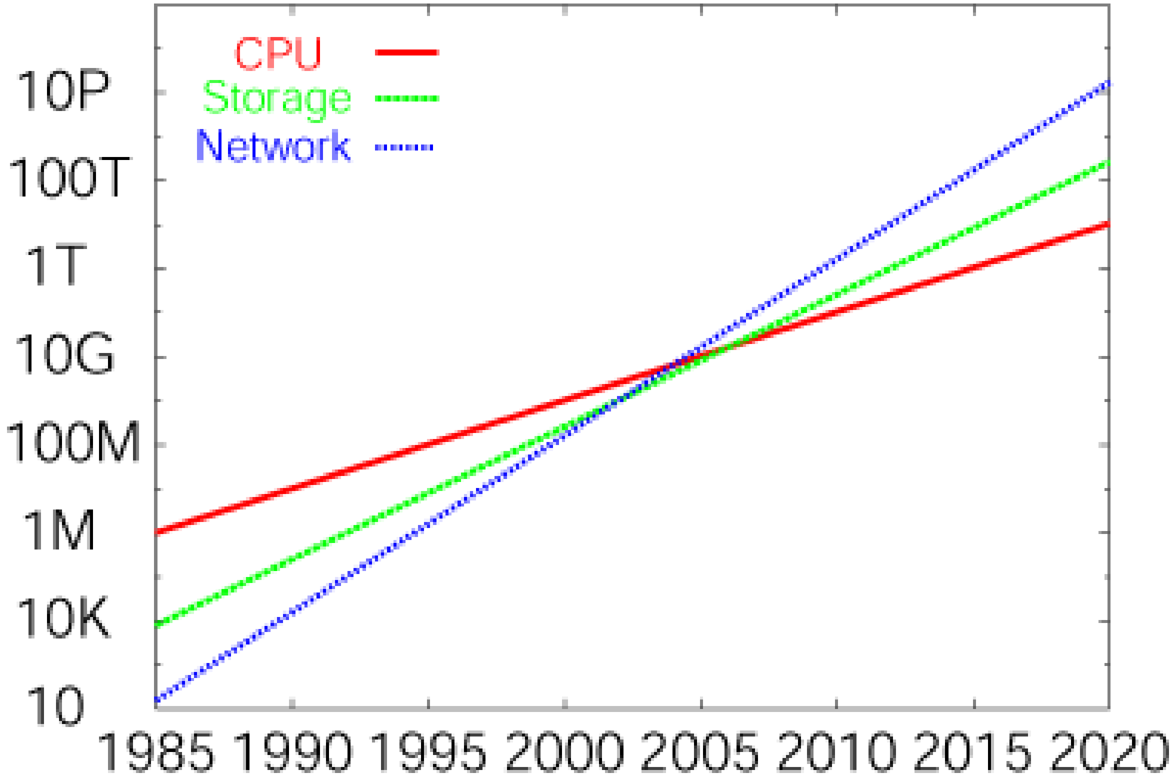
- *A computational grid is a hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to high-end computational capabilities*

  From "The GRID – Blueprint for a New Computing Infrastructure", 1999
  http://www.mkp.com/grids/



# Technology Trend : Grid is feasible!

- CPU speed doubles every 18 months (Moore's law)
- Storage capacity doubles every 12 months
- Network speed double every 9 months




CPU << Storage << Network

# Network is free!

- 100 times in each 5 years
- We can use not only local resources, but also <u>resources in wide area</u>
  - Computers, storage, visualization devices, super computers, special purpose machines, experiment devices, researchers, applications, libraries, data, …

# The Grid Problem (2000)

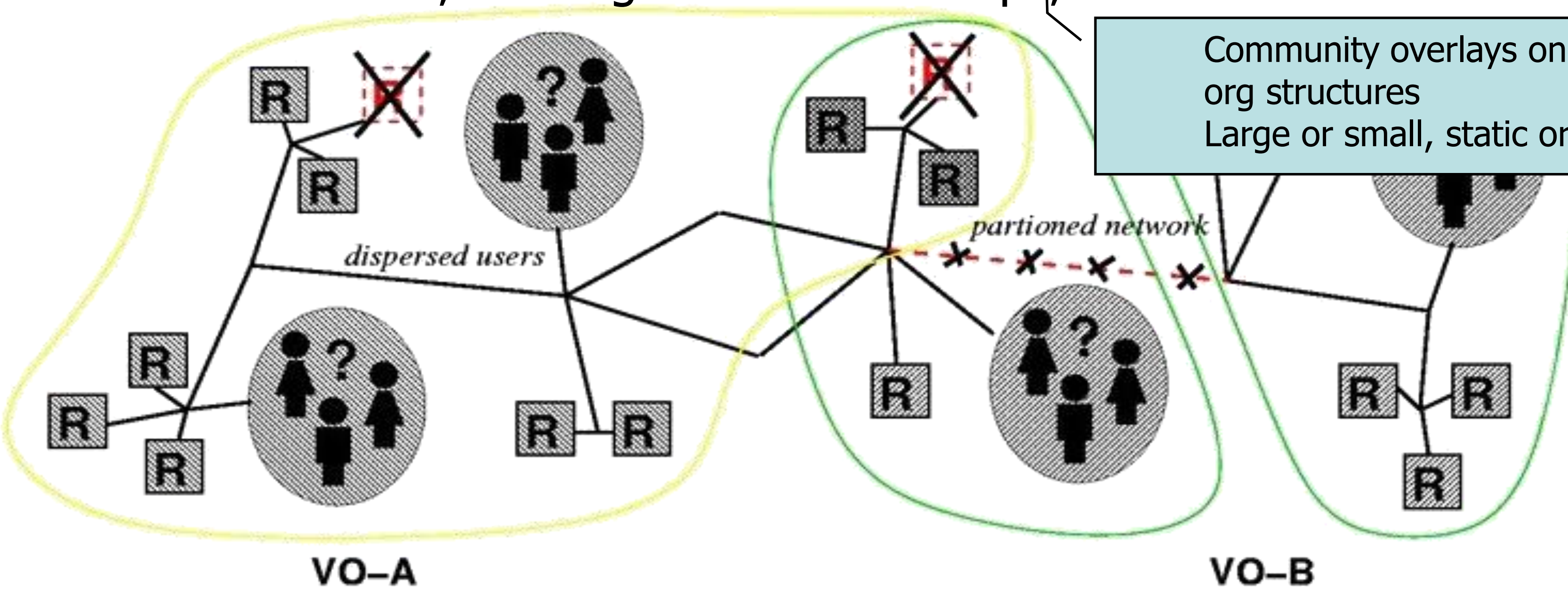
Computers, storage, sensors, networks, …
Sharing always conditional: issues of trust, policy, negotiation, payment, …

Beyond client-server: distributed data analysis, computation, collaboration, …

**Resource sharing & coordinated problem solving in dynamic, multi-institutional virtual organizations**

- Communities committed to common goals
  - Assemble team with heterogeneous members & capabilities
  - Distribute across geography and organization
  - Assuming the absence of central location, central control, omniscience, existing trust relationships, . . .

Community overlays on classic org structures
Large or small, static or dynamic




***Slide courtesy by Ian, Carl, and S. Sekiguchi***

# Virtual organization (VO) and Grid

- **A set of dynamic and flexible resources**
  - Including several institutes managed independently
  - One institute may belong to several VOs
- **Large and small**
- **Secure and controlled resource sharing**
  - Computers, storage, sensor, experiment device, application, data, …
- **Some restrictions**
  - Idle time, only morning, a part of resources, limited programs, …
- **Client-server, P2P**

- **Technology to construct a VO flexibly, and to share resources securely**
  - Secure **authentication** and proper **authorization**
  - Resource **access** protocol, **discovery** protocol
  - **Fault tolerance**
  - **Common** protocol

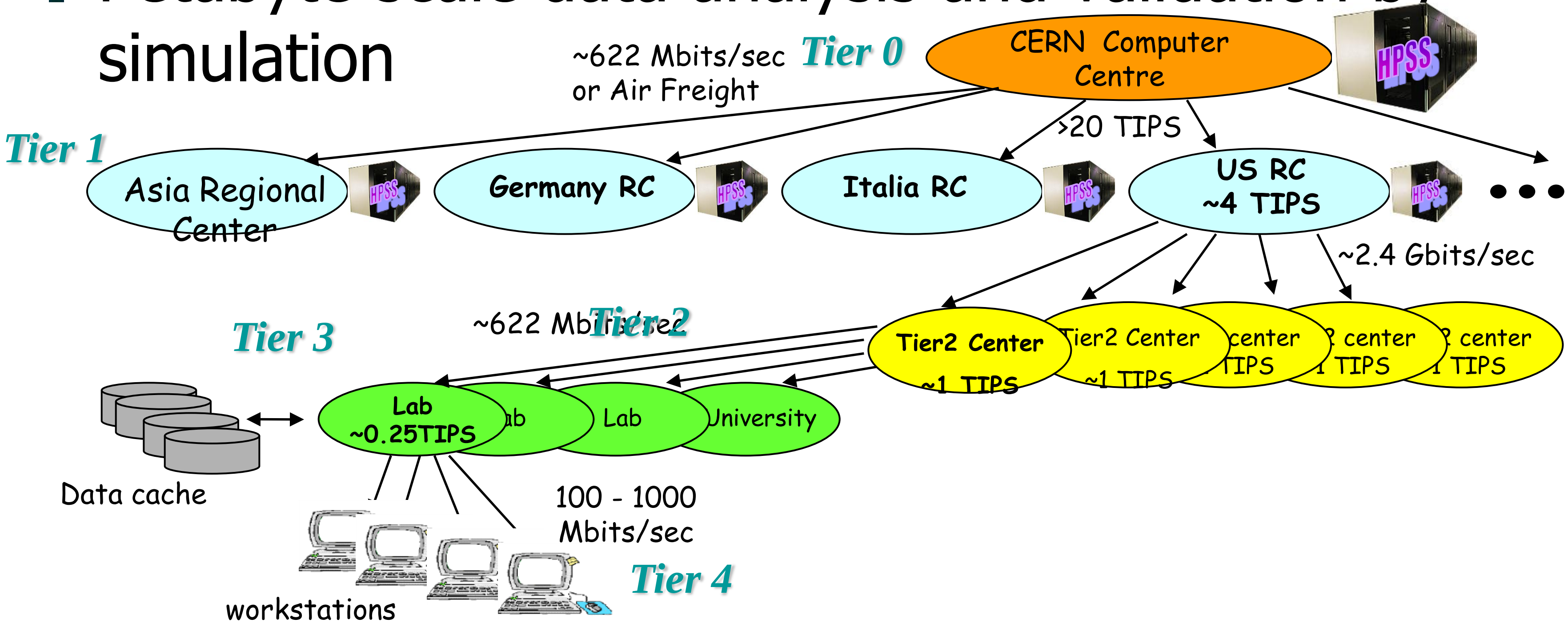
# Several scenarios

- A small VO consisting of companies A and B
- Company A has a supercomputer, Company B has a visualization device
- Both employees shares these resources securely

- A customer would like to introduce a ventilation system
- It is not clear which location is efficient to install due to a complex room structure
- Use an ASP for Computational fluid dynamics simulation, store the result in an SSP, and send it to a house company

# Large scale scenario

- Large Hadron Collider (LHC) experiment
- 3000 researchers in 20 countries
- Hierarchical regional center model
- Petabyte scale data analysis and validation by simulation



# Grid Architecture and standard

# Requirement for Grid Technology

- **Support various security policy required by resource providers and users**
- **Enough flexibility for various resources and sharing policy**
- **Scalability for many resources, many users, many programs**
- **Dynamic resource management**
  - Dynamic extensibility of resources
  - Fault tolerance and self organization
    - Resource status is often changed
- **Efficient execution for large-scale data intensive computing and large-scale simulation**
  - HPC, HTC
  - Support high bandwidth and long latency
- **Standard protocol to share resources flexibly among different groups**
  - Support various resources, policies, protocols
- **Common software stack to avoid duplicate development**

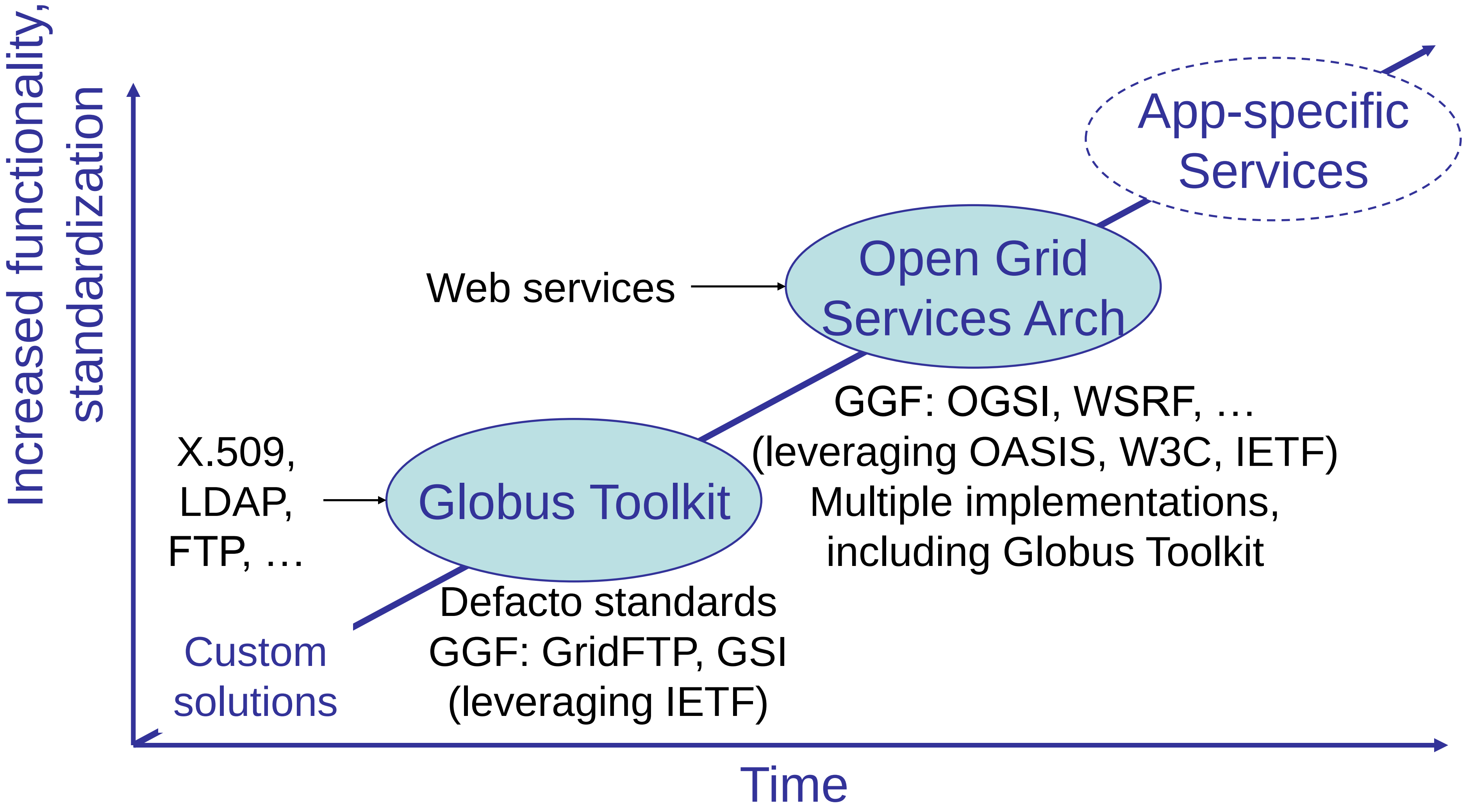
# Standard based Grid Architecture

- **Development of Standard Protocol, Standard Service**
  - Common access protocol to remote resources
  - Based on existent protocols
- **Development of Grid API and SDK**
  - Interface for Grid Protocol and Grid Service
  - Higher level of abstraction to develop applications
- **Success story: Internet**
  - HTTP and HTML
  - TCP/IP, telnet, ftp, mail, . . .

# Important points

- **Based on Internet Protocol, Web Services**
  - TCP/IP, WSDL, SOAP, etc.
- **Define minimum services required for the Grid**
  - Grid Security
  - Addressing – WS-A (WS-Addressing)
    - http://www.w3.org/Submission/ws-addressing/
  - State – WSRF (WS Resource Framework)
    - http://www.oasis-open.org/committees/wsrf/
  - Notification – WS-N (WS-Notification)
    - http://www.oasis-open.org/committees/wsn/

# Evolution of the Grid



# Papers: Grid technology

- Ian Foster, Carl Kesselman. Computational Grids. In The Grid: Blueprint for a Future Computing Infrastructure, Morgan-Kaufmann, 1999. http://dsl.cs.uchicago.edu/papers/gridbook_chapter2.pdf
- I. Foster, C. Kesselman. The Grid 2: Blueprint for a New Computing Infrastructure, Second Edition, ISBN 978-1-55860-933-4, 2003. http://www.mkp.com/grid2
- I. Foster, C. Kesselman, S. Tuecke. The Anatomy of the Grid: Enabling Scalable Virtual Organizations.. International J. Supercomputer Applications, 15(3), 2001. http://www.globus.org/research/papers/anatomy.pdf
- I. Foster, C. Kesselman, J. Nick, S. Tuecke. The Physiology of the Grid: An Open Grid Services Architecture for Distributed Systems Integration.; June 22, 2002. http://www.globus.org/research/papers/ogsa.pdf

# Papers: Web Services

- Web Services Addressing, http://www.w3.org/Submission/ws-addressing/
- Web Services Resource Framework, http://www.oasis-open.org/committees/wsrf/
- Web Services Notification, http://www.oasis-open.org/committees/wsn/

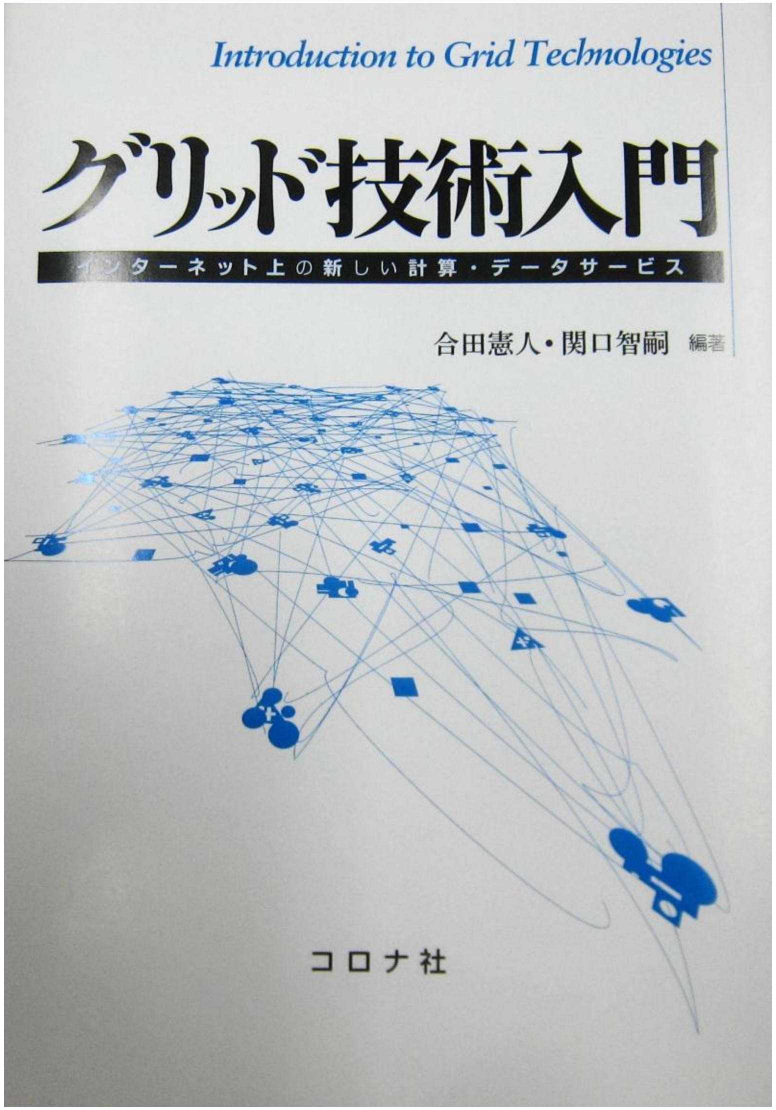
# Papers: Grid Software

- Ian Foster and Carl Kesselman. Globus: A Metacomputing Infrastructure Toolkit. International Journal of Supercomputer Applications, 11(2):115-128, 1997. ftp://ftp.globus.org/pub/globus/papers/globus.ps.gz
- Andrew Grimshaw, Michael Lewis, Adam Ferrari, and John Karpovich. Architectural Support for Extensibility and Autonomy in Wide-Area Distributed Object Systems. University of Virginia CS Technical Report CS-98-12, June 1998. http://www.cs.virginia.edu/~legion/papers/CS-98-12.ps

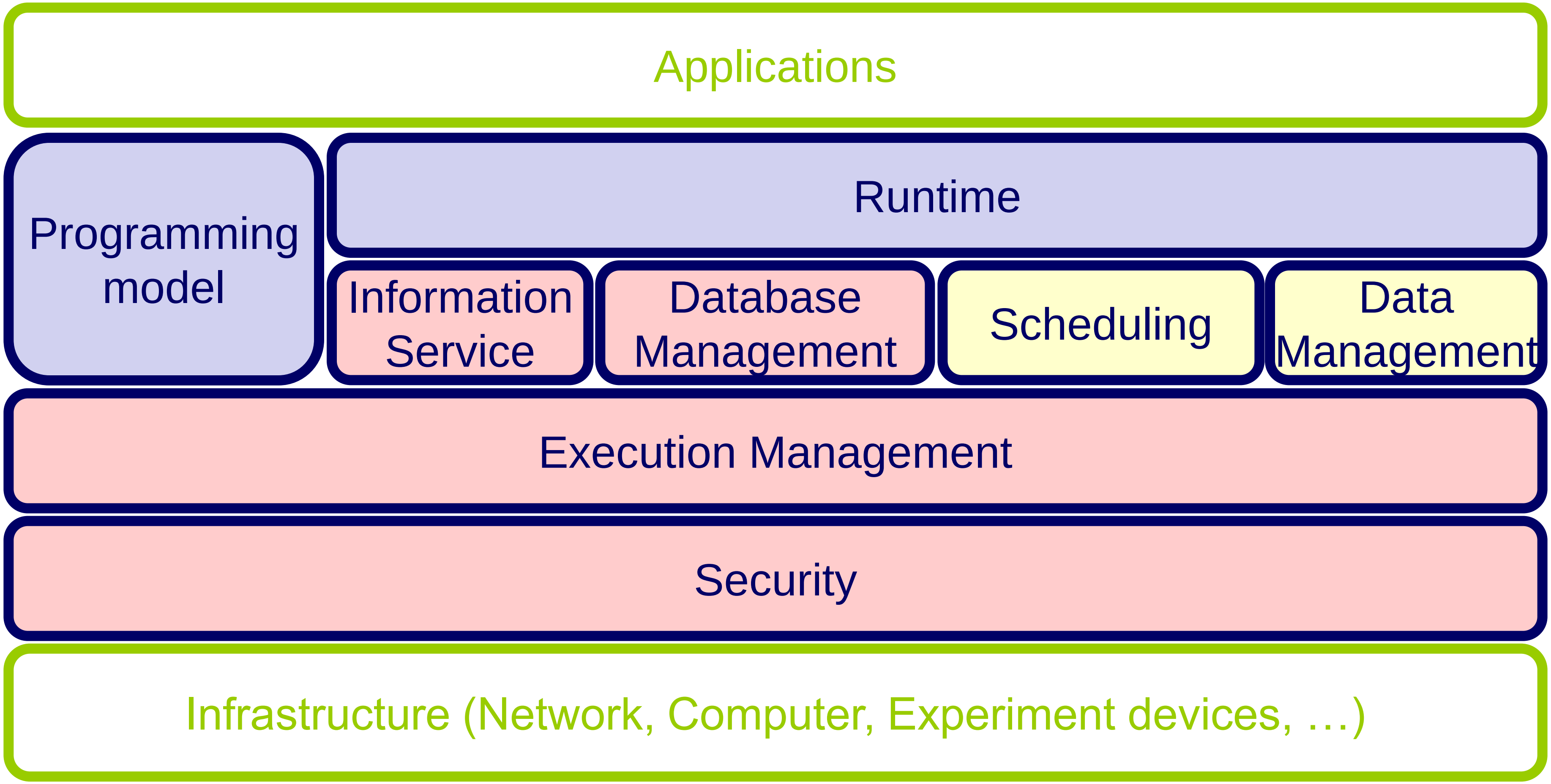
# Grid Technology

# Introduction to Grid Technology

- **New Computational and Data Service in the Internet**
- **Editors: Kento Aida, Satoshi Sekiguchi**
- **Corona publishing, 2008**
- ISBN：978-4-339-02426-5



# Grid Technology (1)



# Grid Technology (2)

- Grid Security Infrastructure (GSI)
- Grid Information Service (GRIS)
- Widearea data transfer (GridFTP)
- Resource Manager (Grid inetd, GRAM)
- Aggregation of Information Service (Grid Index Information Service, GIIS)
- Resource broker (Condor-G, Nimrod-G)
- Data replica management service
- Co-allocation and co-reservation service
- Workflow management service
- . . .

# Grid Security (GSI)

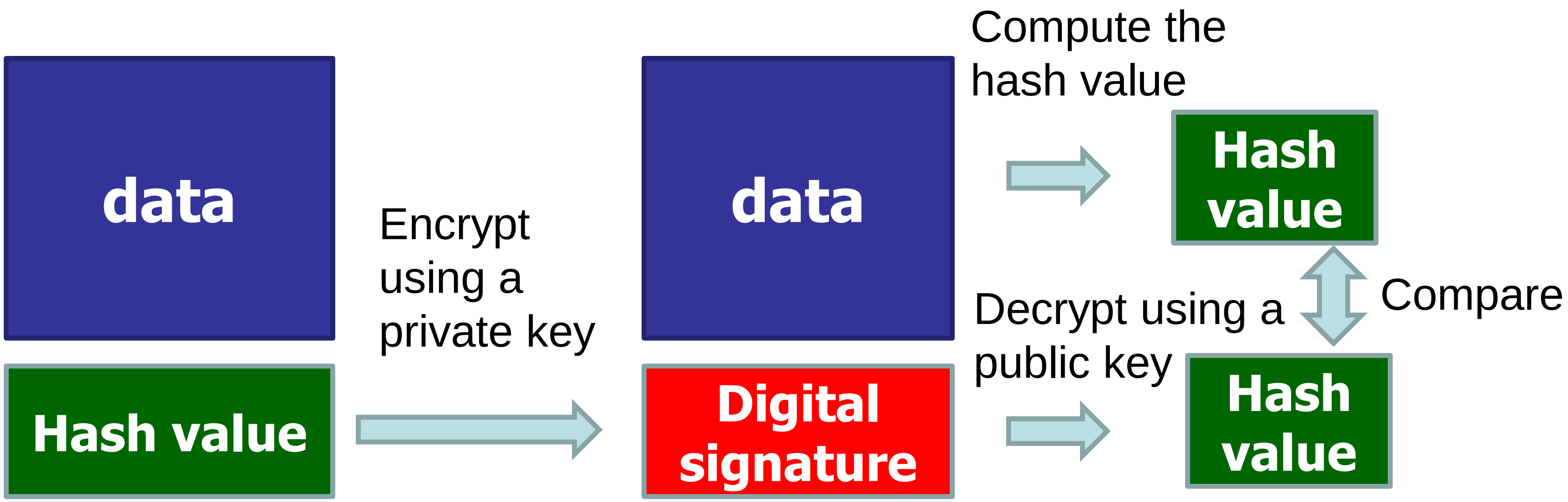
- **Single Sign On**
  - Access authentication and authorization by a single user authentication (pass phrase, one-time password)
- **Certificate delegation**
- **Limit the delegated certificate**
  - Expiration, level of delegations, limited authority
  - Mitigate the damage when it is stolen
- **Support dynamic service creation**
- **Protect a private key**

# Public-key Cryptosystem

- Asymmetric key cryptosystem
- A public key e and a private key d
- Plain text – e → cryptogram – d → plain text
- Computation from e to d is computationally difficult
- A public key not needed to be secret. It is easy to be provided
- Digital signature is required to authenticate a sender and to check a falsification
- Since it is often slow than symmetric key cryptosystem such as DES, it is used to send small messages such as a key of a symmetric key cryptosystem for data transfer of the rest, and credit card information
- Handbook of Applied Cryptography, by A. Menezes, P. van Oorschot, and S. Vanstone, CRC Press, 1996 http://cacr.math.uwaterloo.ca/hac/

# Digital Signature

- Ensure the integrity. The data is not altered or not falsified
- Encrypted hash value of the data
- At a receive side, compare the hash value of the data and decrypted value of the digital signature



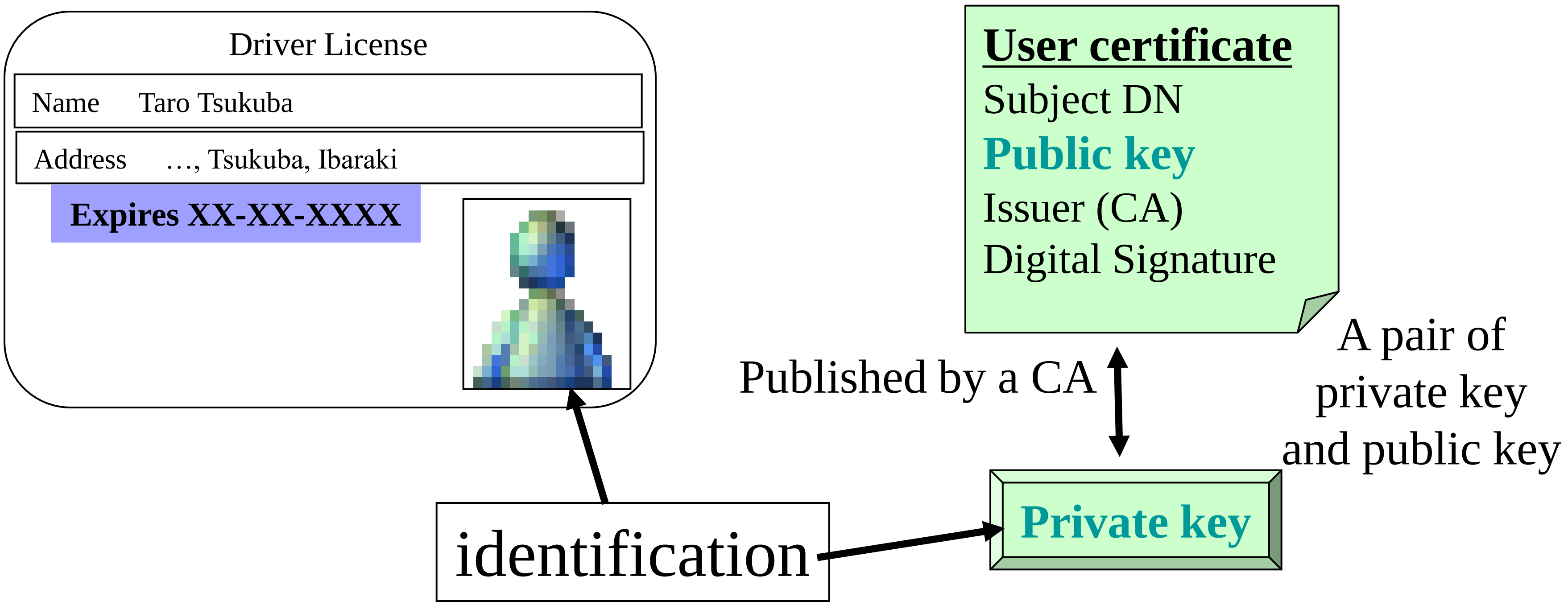
# Grid Security Infrastructure (GSI)

- **Basically public key cryptosystem + X.509 certificate + TLS (Transport Layer Security)**
- **Mutual authentication and certificate delegation using a proxy certificate**
- **Public key cryptosystem (asymmetric key cryptosystem)**
  - Public key is used to encrypt the data
  - Private key is used to decrypt the cryptogram
- **Entity (user, machine, …) keeps a certificate signed by a certificate authority**
- **X.509 certificate includes**
  - Subject name of an entity (user ID, host name)
  - Public key
  - Issuer (Certificate Authority)
  - Digital signature signed by the CA
    - Ensure the certificate is issued by the CA
    - Ensure the Subject name
    - Ensure the relationship of the subject name and the public key

**Certificate**
Subject DN
**Public key**
Issuer (CA)
Digital Signature

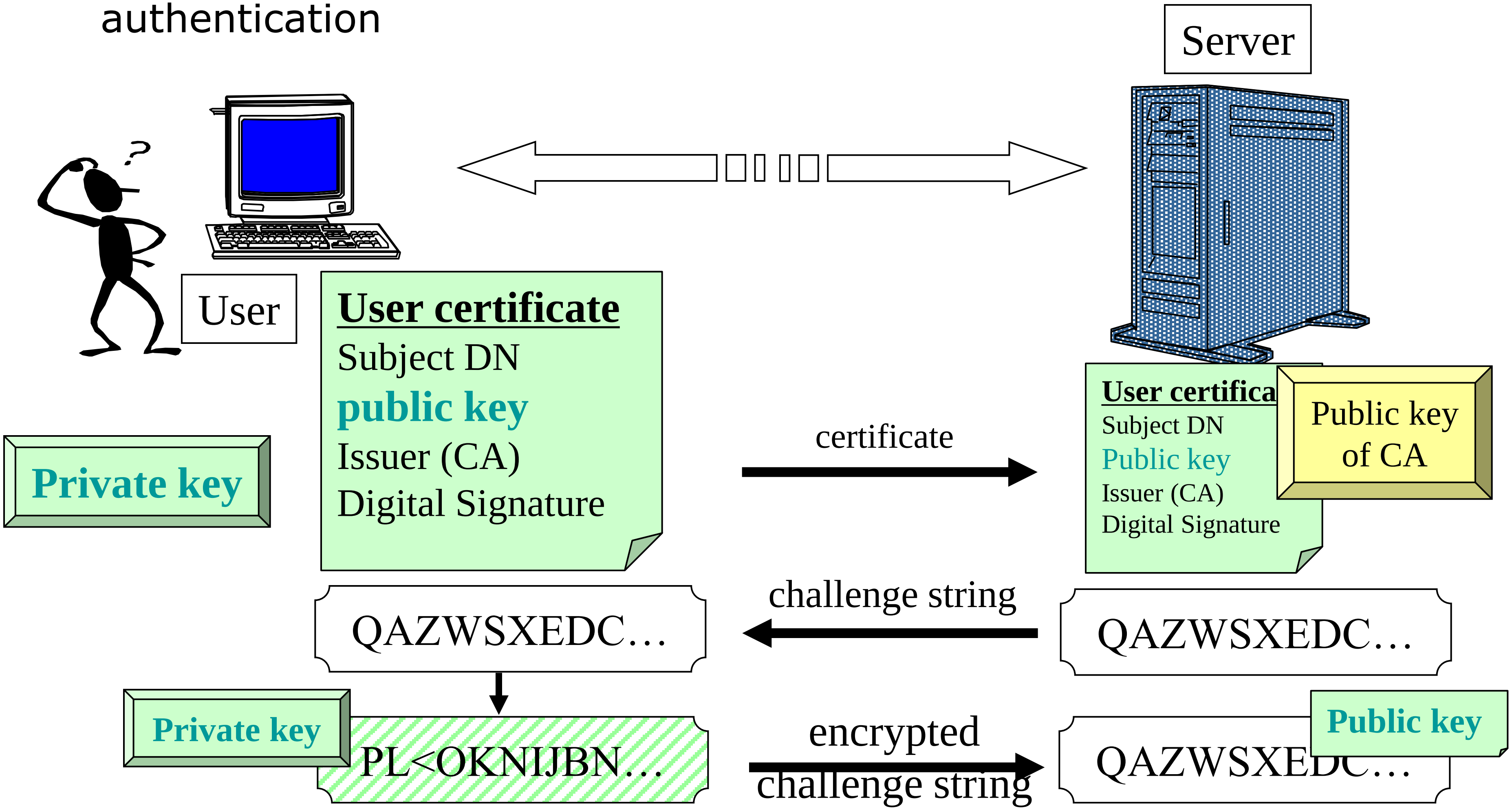
# Certificate

- **It is like a drivers license.  A picture, a method to identify an entity, corresponds to a private key**
- **Signed by a certificate authority**
- **Whether it is credible or not depends on the CA is dependable**



# Authentication by GSI

The following example shows the user authentication, but the server will be authenticated later by the user.  Thus it is called mutual authentication



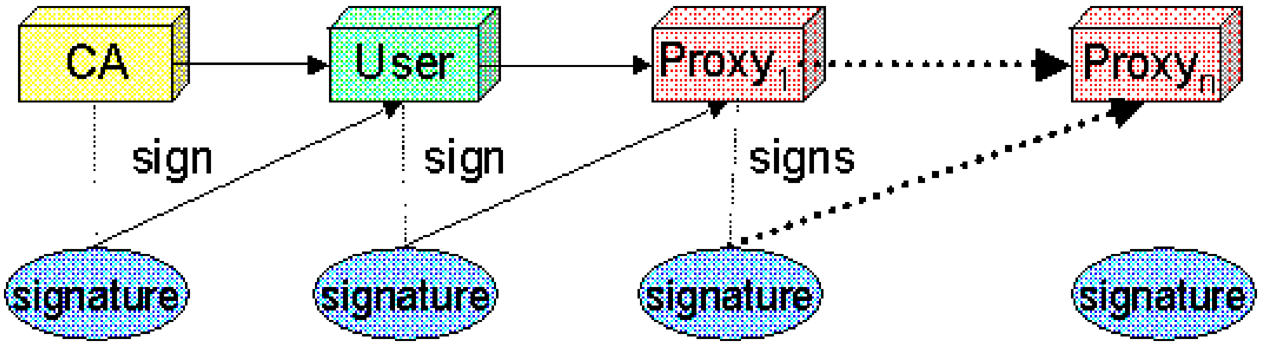
# Extension by GSI

- **Proxy Certificate Profile**
  - Proxy Certificate Profile based on X.509 (RFC 2459)
  - restricted impersonation within a PKI based authentication system.
- **Extension of GSS-API (RFC 2743)**
  - Export and import of the credential
  - Delegation at any point of timing
  - Extension of Credential operation
    - Limited delegation

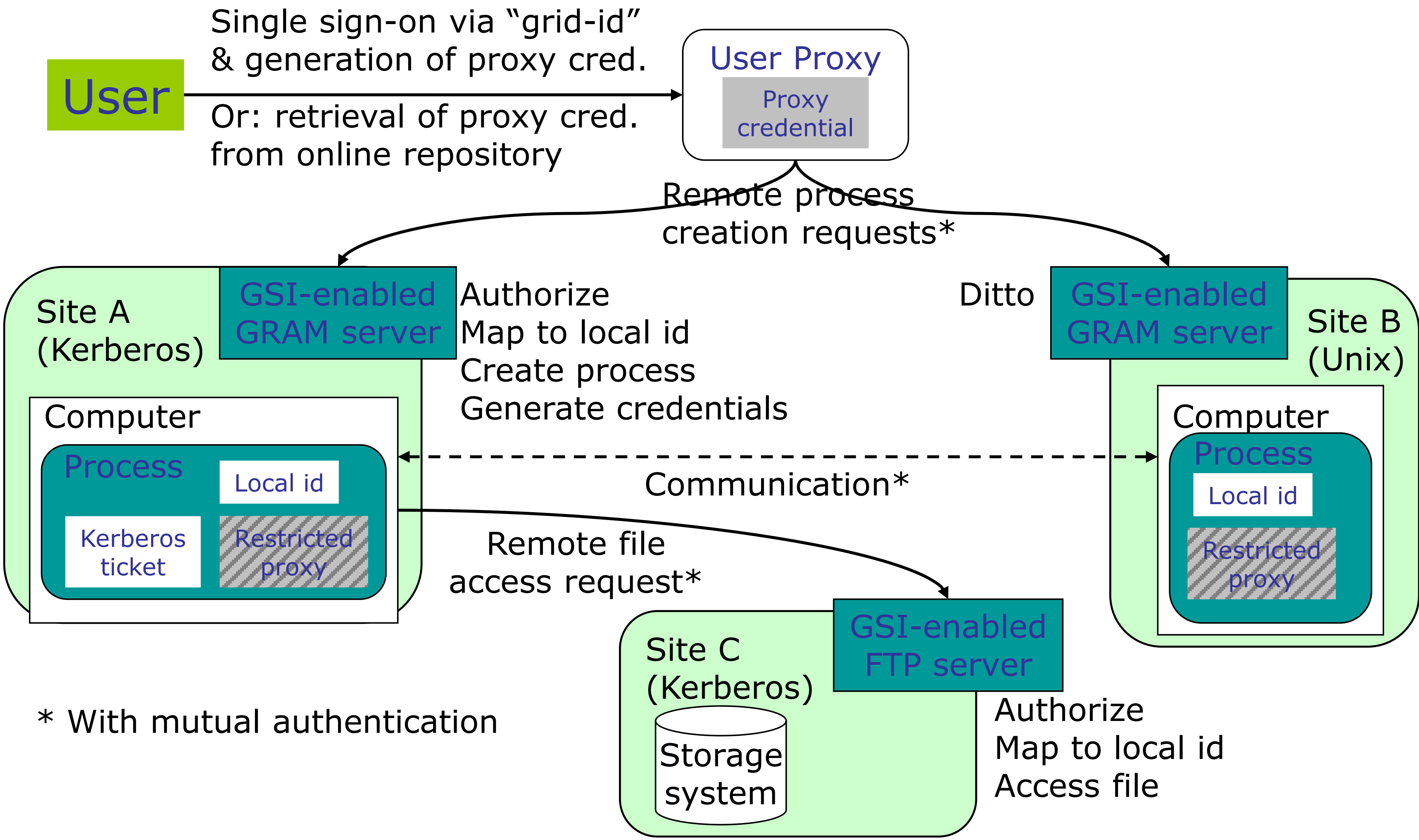
- **Internet X.509 Public Key Infrastructure Proxy Certificate Profile**
  - RFC 3820 by Grid community – OGF
  - GSS-API Extensions
  - ftp://ftp.rfc-editor.org/in-notes/rfc3820.txt

# Delegation of the certificate

- A pair of public and private keys are generated, and signed by a user not a CA
  - Private key is NOT transferred
- Proxy certificate can be validated by the valid user certificate



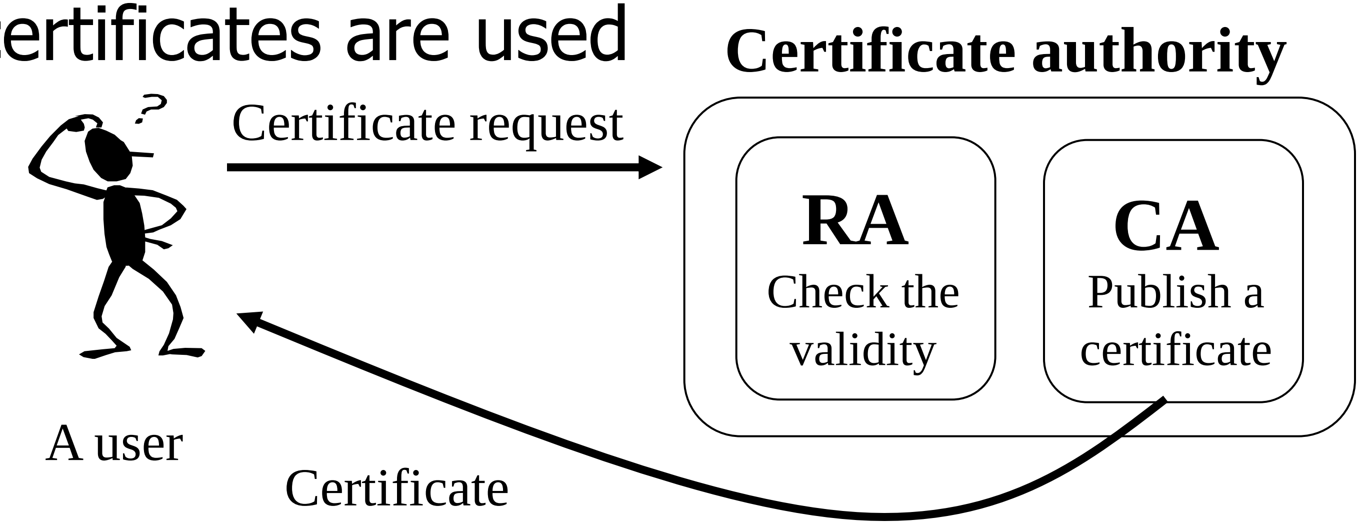
# GSI in Action "Create Processes at A and B that Communicate & Access Files at C"




* With mutual authentication

# Certificate and Certificate Authority

- **Certificate authority**
  - A third party to publish a certificate
  - Two roles: Registration Authority (RA) and CA
    - RA: identify users and computers
    - CA: publish a certificate
  - No way to know how and where published certificates are used



# Initial Setting for Certificate Authority (In case of Globus Toolkit)

- **Setup for a certificate authority**
  - $GLOBUS_LOCATION/setup/globus/setup-simple-ca
    - Subject DN for CA
      - cn=CA, ou=CS, o=Univ Tsukuba, c=JP
    - Email address
    - Expiration date
    - Passphrase for a private key
      - It is used to sign a certificate requested by a user
      - ‘space’ cannot be used
  - $GLOBUS_LOCATION/setup/globus_simple_ca_CA_Hash_setup/setup-gsi -default
    - The public key of the CA is stored at /etc/grid-security/certificates

# How to obtain a host certificate

- **Request for a host certificate**
  - grid-cert-request -host <hostname>
    - /etc/grid-security/hostkey.pem (private key)
    - /etc/grid-security/hostcert_request.pem
    - /etc/grid-security/hostcert.pem (empty file)
- **Ask RA to identify yourself**
- **Send hostcert_request.pem to CA, and ask to be signed**
  - grid-ca-sign -in hostcert_request.pem -out signed.pem
- **Receive the signed hostsigned.pem, and store it at /etc/grid-security/hostcert.pem**
- **Display a content of the certificate**
  - openssl x509 –in hostcert.pem -text

# How to obtain a user certificate

- **Request for a user ceritificate**
  - grid-cert-request
    - ~/.globus/userkey.pem (private key)
    - ~/.globus/usercert_request.pem
    - ~/.globus/usercert.pem (empty file)
- **Ask RA to identify yourself**
- **Send usercert_request.pem to CA, and ask to be signed**
  - grid-ca-sign -in usercert_request.pem -out signed.pem
- **Receive the signed signed.pem, and store it at ~/.globus/usercert.pem**

# Authorization by GSI

- **Register to Grid-mapfile**
  - Grid-mapfile-add-entry -dn “/C=JP/O=Univ Tsukuba/OU=CS/OU=tatebe.net/CN=Osamu Tatebe” -ln tatebe
    - Add an entry to /etc/grid-security/grid-mapfile

# Setting of GSI-enabled OpenSSH

- **Copy $GLOBUS_LOCATION/sbin/SXXsshd to /etc/init.d/gsisshd**
- **service gsisshd start**

# Proxy Certificate and login

- **Create a proxy certificate**
  - grid-proxy-init [ -debug ] [ -veriry ]
- **Display the certificate**
  - grid-proxy-info
- **Login using GSI authentication**
  - gsissh hostname
  - User proxy certificate will be delegated
- **FTP using GSI authentication**
  - gsisftp hostname

# Papers: Grid Security

- Ian Foster, Carl Kesselman, Gene Tsudik and Steven Tuecke. A Security Architecture for Computational Grids. Proc. 5th ACM Conference on Computer and Communication Security, 1998. ftp://ftp.globus.org/pub/globus/papers/security.ps.gz
- Eshwar Belani, Amin Vahdat, Thomas Anderson, and Michael Dahlin. The CRISIS Wide Area Security Architecture. Proc. USENIX Security Symposium, January 1998. http://now.cs.berkeley.edu/WebOS/papers/uss.ps

# Information Service

- **Discovery, monitoring, planning, basic mechanism for adaptive applications**
- **Various, many, dynamic, geographically distributed resources**
- **Fault tolerance**
  - Network disconnectivity and node failure are the norm not exceptions
- **Information**
  - IP address, administrator
  - CPU, OS, software
  - Network bandwidth, latency, protocol, logical topology
  - CPU load, network load, disk usage, load
  - . . .

# Usage Scenario of Information Service

- **Service discovery service**
  - Find a new service
- **Super scheduler**
  - Select appropriate computational resources depending on system configuration, CPU load, …
- **File replica selection service**
  - Choose most appropriate file copy
- **Adaptive application agent**
  - Change application behavior depending on runtime resource situation
- **Failure discovery service**
  - Find too much load, and failure
- **Performance monitoring**
  - Examine a bottleneck of performance

# Requirement (1)

- **Distribution of information providers**
  - All information is old due to the distribution
  - Need the confidence of the information
    - Timestamp, expiration date, …
  - Transfer the information as soon as possible
  - Generally speaking, no need to provide consistent view of the global status
    - If it provides, the system does not scale to the number of providers

Focus on efficient information transfer from a single source

# Requirement (2)

- **Cope with failure**
  - Resources and network tend to fail
  - Should be fault tolerant
    - A single failure should not prevent from collecting information of other resources
    - Provided information may not be complete, or inconsistent
- **Information service should be distributed and not centralized as much as possible**
  - Increase possibility to obtain information of available resources
- **Should assume failure is not an exception but the norm**

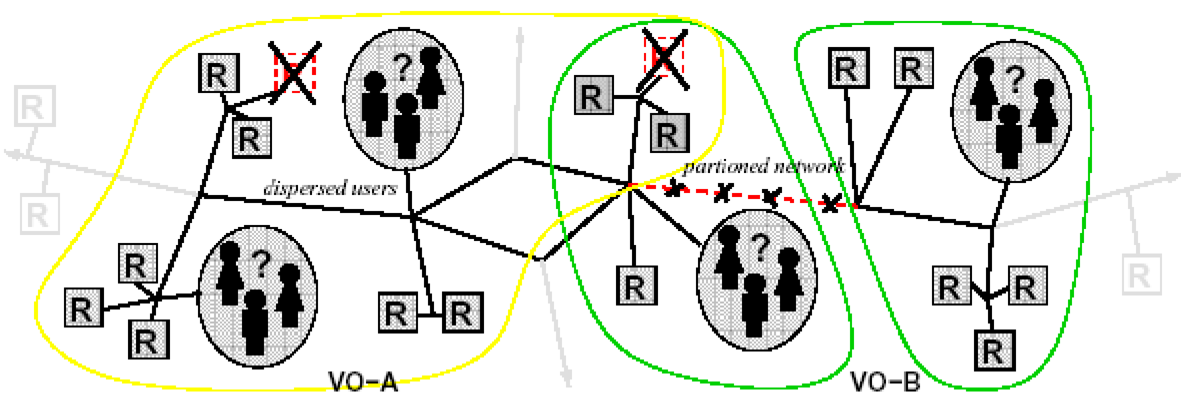


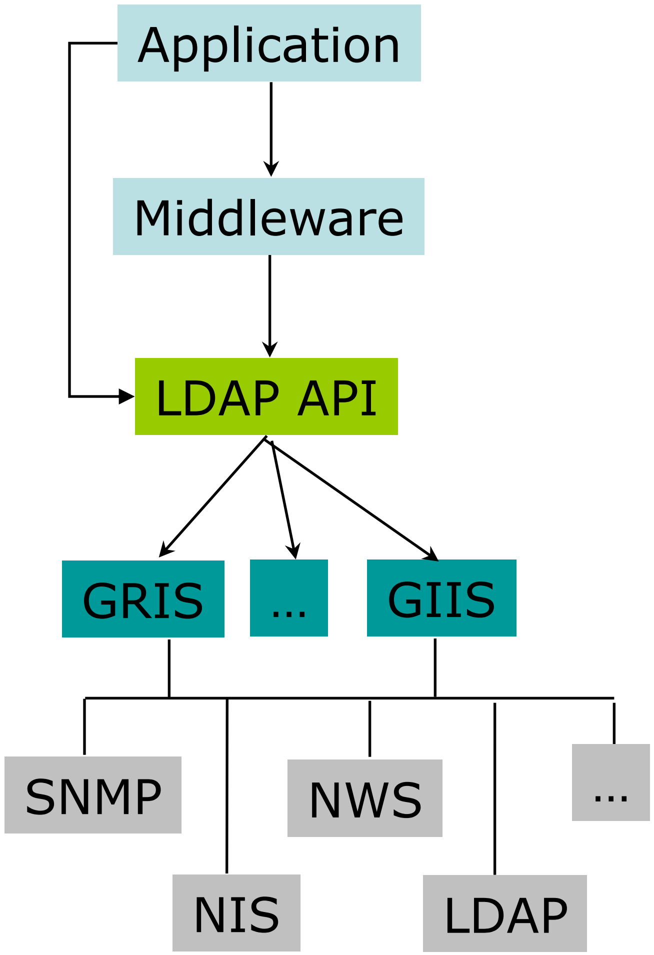

Figure 1. Distributed virtual organizations. Users in VO-A and VO-B have access to partially overlapping resources. While VO-B is split by network failure, it should operate as two disjoint fragments.

# Requirement (3)

- **Variation of information service component**
  - There are various kinds of resources.  Some may require a special requirement to discover and to monitor
  - Various kinds of discovery and monitoring methods
  - Various kinds of access policy since resources are located in several administration domains
    - Access control

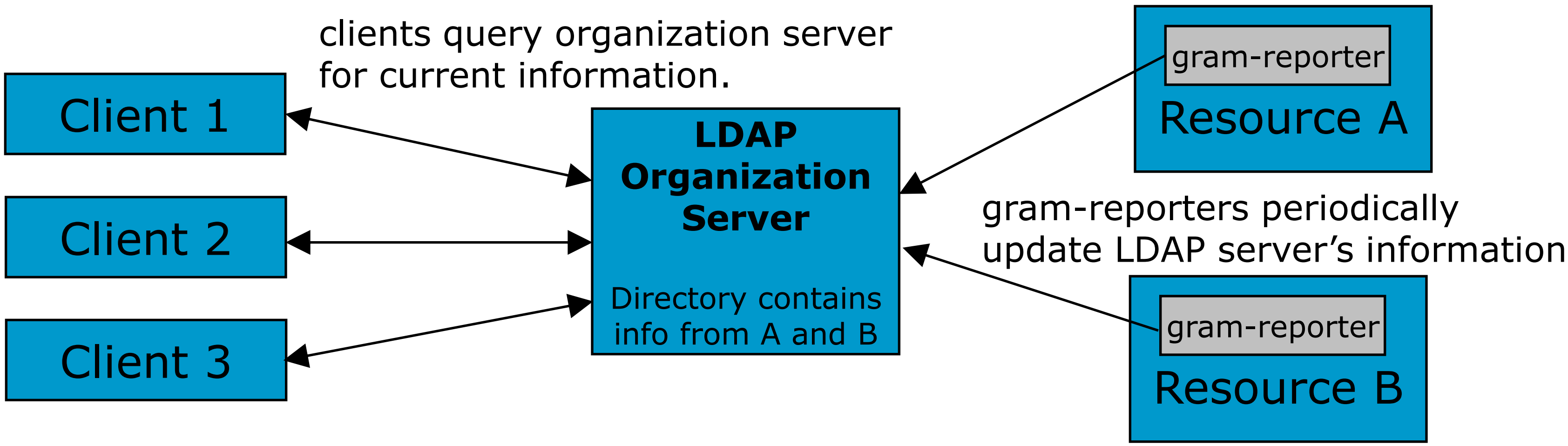
# Globus MDS Approach

- **Based on LDAP**
  - Lightweight Directory Access Protocol v3 (LDAPv3)
  - Standard data model
  - Standard query protocol
- **Globus Toolkit schema**
  - Host-centric representation
- **Globus tools**
  - GRIS, GIIS, gram-reporter
  - Data discovery, publication,…



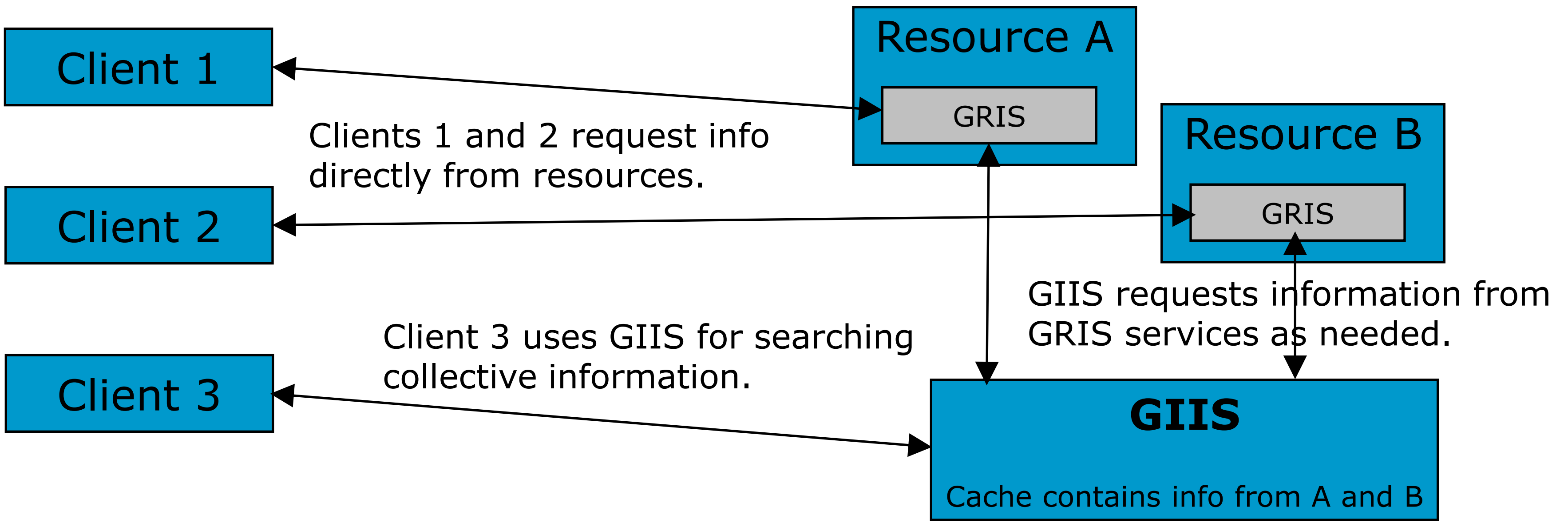
# “Classic” MDS Architecture

- Resources push information into a central organization server via regular updates (globus-gram-reporter), where it can be retrieved by clients.
- Regular updates don’t scale as the number of resources grow rapidly. Commercial LDAP servers are optimized for “read” requests, and can’t handle frequent “write” requests.
- If organization server is unavailable, no information is available.



# “Standard” MDS Architecture (v1.1.3)

- Resources run a standard information service (GRIS) which speaks LDAP and provides information about the resource (no searching).
- GIIS provides a “caching” service much like a web search engine. Resources register with GIIS and GIIS pulls information from them when requested by a client and the cache as expired.
- GIIS provides the collective-level indexing/searching function.



# Component of MDS (Metacomputing Directory Service)

- **Grid Resource Information Service (GRIS)**
  - Provide the information of a single resource
  - Multiple information providers can be supported
  - LDAP protocol to inquire
- **Grid Index Information Service (GIIS)**
  - Provides the information collected by multiple GRIS servers
  - Help to provide the information distributed by multiple GRIS servers
  - LDAP protocol to inquire

# Papers: Information Service

- K. Czajkowski, S. Fitzgerald, I. Foster, C. Kesselman. Grid Information Services for Distributed Resource Sharing. Proc. Tenth IEEE International Symposium on High-Performance Distributed Computing (HPDC-10), IEEE Press, August 2001. http://www.globus.org/research/papers/MDS-HPDC.pdf