Trends and R&D in Cloud Computing

August 2010

For enquiries, please contact :
Low Wai Chong
Head, Infocomm and Computing
Science & Engineering Research Council
Agency for Science, Technology and Research (A*STAR)
1, Fusionopolis Way, #18-10 Connexis North
Singapore 138632
Email : Low_Wai_Chong@a-star.edu.sg

How to cite this article:
White Paper on Cloud Computing by the Science and Engineering Council, Agency for Science, Technology and Research. Aug 2010.
<http://www.a-star.edu.sg/AboutASTAR/ScienceandEngineeringResearchCouncil/StrategicThrusts/tabid/516/Default.aspx>

TRENDS AND R&D IN CLOUD COMPUTING

AIM

1. This paper reviews current trends in cloud computing, and discusses A*STAR's position on R&D for cloud computing.

INTRODUCTION AND GLOBAL TRENDS

2. In any enterprise, IT infrastructure and support are constantly facing cost pressures, while computing needs and amount of data are ever increasing.

3. Cloud computing has emerged in recent years as a new model for the delivery and consumption of IT resources. With cloud computing, enterprises can easily pay for access to a service provider's IT resources, such as platforms, infrastructure, software applications, without actually owning the resources.

4. In this way, enterprises avoid capital investment in fast-depreciating IT resources and reduce operational cost, while being able to adapt to users' computing needs. Without the burden of operating and maintaining IT resources, enterprises can then better focus on their core business and competencies.

5. National Institute of Standards and Technology (NIST) defines cloud computing as a model of enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [1]. Broad network access ensures that capabilities are accessible through heterogeneous platforms such as mobile phones, laptops, and portable devices. The pay-per-use metered usage model results in better resource optimisation, because the service provider's computing resources are pooled to serve multiple consumers.

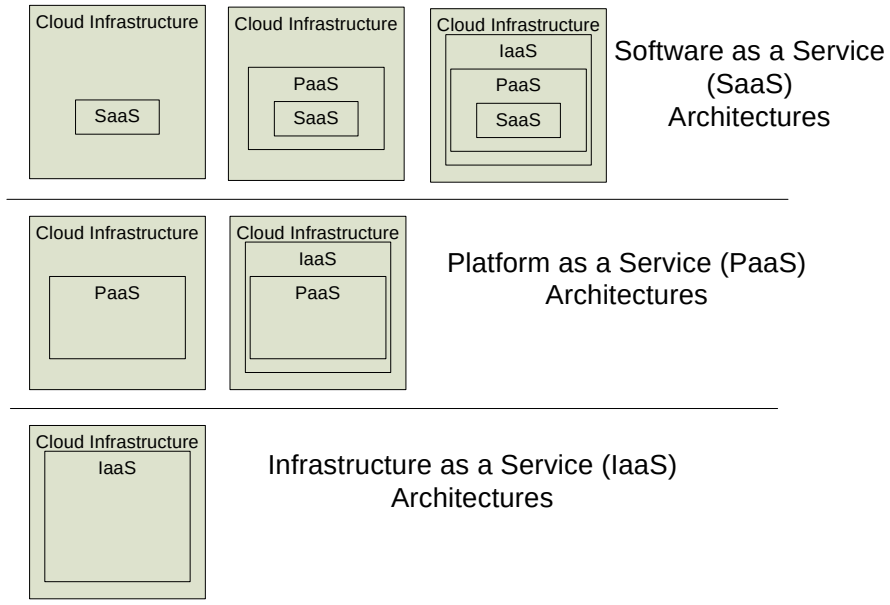
6. There are three usage models for cloud:

   a. Software as a Service (SaaS). Consumer uses the service provider's applications running on a cloud infrastructure. Examples of this usage model include Google's web-based email, word processing and spreadsheet applications, and Salesforce's customer relationship management application.

b. Platform as a Service (PaaS). Consumer deploys onto the cloud infrastructure applications created using programming languages and tools supported by the provider. Examples include Google's App Engine and Salesforce's force.com platform.

c. Infrastructure as a Service (IaaS). Consumer can provision processing, storage, networks, and other fundamental computing resources to deploy and run software, which can include operating systems and applications. One such example is Savvis, which provides IT infrastructure for companies. Based in Singapore, Alatum and nGrid deliver on-demand infrastructure and software, while PTC Systems offers storage as a service.

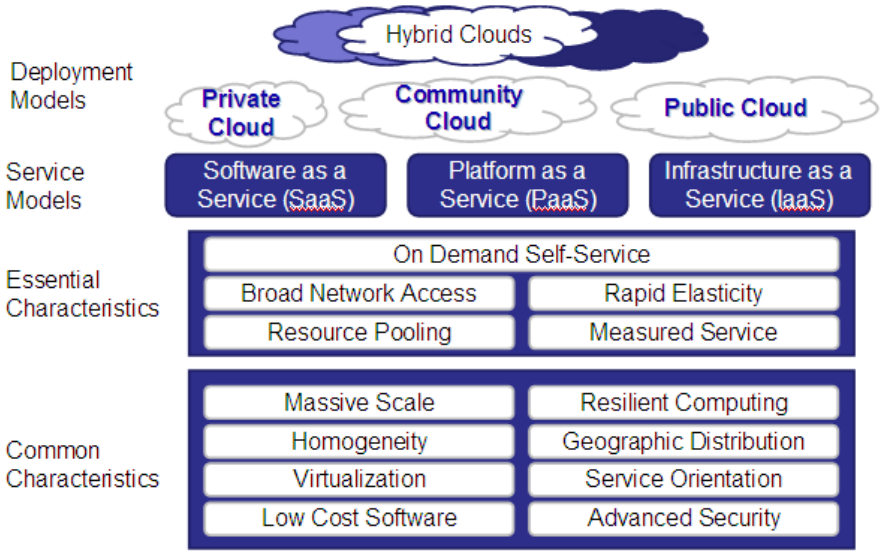
Figure 1. Service Architecture Models



(Source: NIST)

7. The cloud infrastructure could be operated solely for an organisation (private cloud), shared by a group of organisations (community cloud), or shared with the general public (public cloud). There are also hybrid clouds which have two or more clouds. Companies may choose between the models, each of which has their merits and trade-offs. For example, private clouds may provide the best control over data, security and quality of service, while public clouds may be best suited to provide flexible IT infrastructure on demand.

Figure 2. Cloud Models and Characteristics



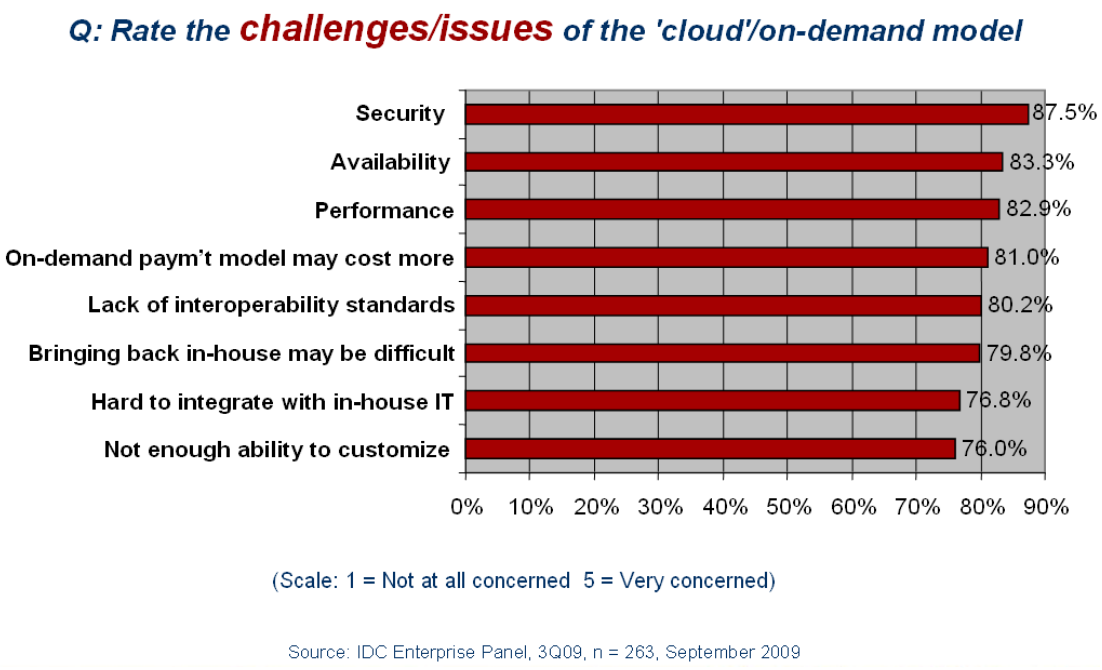
(Source: NIST)

8. Gartner identified Cloud Computing and Advanced Analytics as the top two strategic technologies for 2010 with the most potential for significant impact on the enterprise, based on their high potential for disruption to IT or the business, the need for major dollar investment, or the risk of being late to adopt. [2] In addition, worldwide cloud revenue is expected to grow from US$58.6 billion in 2009 to US$148.8 billion in 2014. [3]

9. In a separate survey by Pew Research Centre, the majority of respondents believe that they will “live mostly in the cloud” in the year 2020. The respondents believed that cloud computing will continue to expand and dominate information transactions, allowing users easy, instant and individualised access to tools and information from mobile phones or any networked device. [4]

10. However, there are challenges to overcome, in areas such as security, performance and availability. In security, for example, as users transfer their data and tools to a cloud service provider, the trustworthiness of the cloud vendor’s security model would be a risk issue. The IT Standards Committee in Singapore is looking into standards in areas such as security, privacy and interoperability of data stored in the cloud.

Figure 3. Major challenges in cloud computing



BUILDING SINGAPORE'S CLOUD COMPUTING ECOSYSTEM

11. Singapore has been actively involved in developing strategies for cloud computing, has built up a good broadband infrastructure, and provides a living lab for testbedding and developing a cloud computing ecosystem. These factors have helped to attract cloud companies to Singapore and increased the adoption of cloud services.

12. Developing broadband infrastructure and connectivity. Singapore is a key node for data centre and network operators, with excellent local and international connectivity. The Next Generation Nationwide Broadband Network will enhance broadband connectivity within Singapore, while high-capacity cable networks provide connectivity to other countries. The availability of broadband will drive up the usage of cloud.

13. Providing a testbed for cloud applications. Government agencies' efforts are encouraging testbeds for new cloud technologies.

    a. IDA, Yahoo, HP and Intel, launched the Open Cirrus Cloud Computing Testbed in 2008 to develop local research in internet-scale data-intensive computing, through working with overseas technology partners. The international research collaboration aims to further study

provisioning technologies and explore new cloud computing paradigms.

b. Fusionopolis provides a testbed for infocomm and media applications, with opportunities for collaboration in cloud computing between industry partners such as HP Labs and A*STAR RIs. HP Labs Singapore, the 8th facility worldwide and an open innovation hub in Asia Pacific, was launched in Feb 2010 and plans to work on future concepts in data centre and its relations with cloud computing.

c. IBM Cloud Lab Singapore, in collaboration with IDA, was launched in May 2010 to develop innovative, repeatable, first-of-its-kind solutions to address challenges and problems encountered by users in the government and industry.

14. Attracting key service providers & encouraging user adoption. With the help of government efforts, some major cloud service providers have set up operations in Singapore, and cloud adoption is set to increase.

a. Salesforce, HP Labs, IBM and Amazon have either set up data centres or launched cloud services in Singapore within the past year.

b. To assist companies in cloud adoption, IDA and software company Platform Computing collaborated to set up a Cloud Innovation Centre to provide business and technology consultancy and training programmes in cloud computing. The centre aims to help organisations undertake trials and proof-of-concept in enterprise cloud adoption, before proceeding to production.

c. Singapore is well poised to build a cloud ecosystem with an increasing number of service providers and cloud users. As an example, the Ministry of Education is the first to adopt Google Apps to roll out standardised collaboration and communication services to its 30,000 teachers in 2009.

d. NTU is collaborating with IBM to develop a computing-on-demand platform, leveraging on its high performance computing facility with the flexibility of the cloud. NUS is studying dynamic provisioning of high performance computing and charging models, and their Biochemistry Department is also looking into moving bioinformatics data into the cloud with Amazon Web Services as a solution to overwhelming storage problems.

e. IDA has articulated to the Internet of Knowledge (IOK) committee the need to intensify translational R&D in cloud. The objective is to bridge the gap between research activities and industry needs. The suggested approach will involve identifying specific industry needs and having a fund that can be used to commission R&D.

15. IDA has recognised a fundamental shift of consumer and enterprise needs to “Information Analysis”. In IDA’s “Internet of Knowledge” concept, cloud computing is a way of rationalising infrastructure needs, providing an internet-scale platform to collect, store and process data. IDA has identified the following strengths for Singapore in developing this Internet of Knowledge [5]:

a. Singapore is an established Asian gateway for flow of goods, information, money; with 7,000 MNC regional HQs already located here;

b. Singapore provides world-class infrastructure and global connectivity;

c. Strong IP protection and trusted legal framework exists for knowledge work;

d. Lead demand user and strong foundation sectors such as: education, eGov, finance, healthcare, logistics, urban planning;

e. Strong system integration know-how & execution skills; and

f. Cosmopolitan city with favourable innovation & living environment for high end knowledge talents.

16. Similarly, the opportunities for Singapore for an Internet of Knowledge are:

a. Ability to connect the dots and integrate resources is a key opportunity for Singapore to perform better, faster than others based on insights, creating unique value propositions (e.g. data-value-chain-as-a-service);

b. Singapore can be a trusted advisor to provide insights to local, regional and international customers; and

c. Internet of Knowledge is a new source of competitive advantage and exportable service, leading to higher productivity.

A*STAR'S ROLE IN DEVELOPING CLOUD COMPUTING

17. A*STAR has been actively involved in grid & distributed computing during the past decade into the present, in building up Singapore's base for cloud computing and essential capabilities to support cloud computing projects.

18. Participating in international & national committees. IHPC has participated in numerous key committees to build up grid and cloud computing capabilities:

a. NGO's National Grid Advisory Committee - The committee was set up to provide leadership and direction for the National Grid Office (NGO), whose charter is to increase awareness and adoption of grid computing in the industry, and has gradually evolved into pushing cloud computing as there is a more viable business model for this paradigm.

b. IDA's Internet of Knowledge Committee - The committee consists of representatives from different government agencies to map out responses to the ESC report in terms of new initiatives that can be established in the infocomm sector. The committee focuses on 3 broad areas: cloud computing, data analytics and intelligent interfaces.

c. Pacific Rim Application and Grid Middleware Assembly (PRAGMA) – PRAGMA was formed in 2002 to establish sustained collaborations and advance the use of grid technologies in applications among a community of investigators in leading institutions around the Pacific Rim.

d. Hewlett-Packard Consortium for Advanced Scientific and Technical (HP-CAST) – The users group works to increase the capabilities of HP solutions for large-scale, scientific and technical computing.

e. Microsoft Technical Computing Executive Advisory Committee.

f. OpenCirrus – An international research organization involving HP Labs, IDA Singapore, Yahoo, Intel, and others to further study the computational service provisioning technologies and explore new computing paradigm in cloud computing environments..

19. Collaborating with HP Labs. IHPC collaborated with HP Labs Palo Alto on the Shared Services Platform project from 2006 to 2009, in topics related to utility computing and service automation. Novel computing paradigms and frameworks were established, resulting in numerous key publications, a book chapter and a patent application. The successful collaboration, in conjunction with HP's confidence that Singapore provides an ideal ecosystem in support of R&D, led to HP Labs' decision to set up a full-scale research lab here.

20. Building core capabilities. SERC RIs have core expertise relevant to support cloud computing:

a. IHPC has built capabilities in cloud computing middleware, platforms and tools. For instance, it has developed service provisioning technologies under the A*STAR Digital Nervous System project (2006-2009), and service automation and management technologies in the HP Labs Shared Services Platform collaboration. Also, IHPC has developed a set of tools for provisioning high performance computing as a service. IHPC also possesses HPC expertise to develop efficient algorithms to analyze big data quickly, which is essential to enable quick decision-making in businesses. These capabilities are relevant to the IOK committee's recommendation on cloud computing and business analytics.

b. I^2R has competencies in areas such as security protocols, authentication and data privacy protection.

c. DSI has capabilities in storage systems and is moving into higher level storage services.

d. Both IHPC & I2R's capabilities in data mining and visualisation can enable analysis of large data sets.

e. SERC's Optical Network Focused Interest Group (ONFIG) developed optical access network technologies and demonstrated the industrial applications using the Fusionlight testbed.

21. Collaborating in new projects. SERC RIs are currently involved in the following cloud computing initiatives and projects:

a. SERC's TSRP on Data-Value-Chain-as-a-Service was established to understand and address the challenges associated with managing and analyzing big, heterogeneous and distributed data in the cloud. The TSRP, through the portfolio of projects that are awarded,

attempts to enable the end-to-end lifecycle of collecting, storing, securing, curating, transforming, integrating, analyzing and visualizing complex enterprise/business data. Data analytics promise abilities to extract data and analyze it for richer understanding, which may involve visualisation and simulation, and cloud offers a plausible platform for the sharing of data from different domains and organizations. IHPC, I^2R and DSI are collaborating with NUS and NTU professors to establish multi-disciplinary capabilities in various industry verticals.

b. A collaboration on "Circadian pattern identification and validation" by I^2R and IHPC aims to enable efficient collection and processing of stream data from wearable healthcare sensors. The platform and application will be tested and demonstrated using Amazon EC2 cloud computing resources.

c. IHPC was awarded an IDA grant under the Open Cirrus cloud computing scheme for a project entitled "Fault tolerance for Hadoop", to investigate fault-tolerant techniques to improve the reliability of Hadoop-based services in public cloud environments.

d. IHPC is working with various industry parties on areas such as logistics optimization and engineering based modelling services to provide cloud-based solutions for multi-disciplinary industrial and engineering problems.

e. IHPC has organized workshops to train fire safety engineers in running fire and smoke simulations using cloud computing technologies. The results of such simulations are used toward the certification of new buildings for compliance to established fire safety regulations. Local service providers are interested to provide such services as commercial offerings.

A*STAR'S POSITION IN CLOUD COMPUTING

22. Singapore has built up the supply side of the cloud ecosystem in attracting data centres and service providers. Going forward, the focus should be on the demand side. The National Grid Advisory Council has requested the National Grid Office to start engagement and discussion with targeted user verticals. A*STAR is represented on the NGAC and will be privy to the opportunities that will be highlighted during the engagement.

23. Infrastructure-as-a-Service (IaaS) is rather mature now. Amazon, Salesforce, Microsoft, local providers and many other

players already have offerings in IaaS. Going forward, A*STAR should move away from this cloud layer and pay more attention to technologies that are needed to enable complex, value-added services and to make cloud more efficient, reliable and secure.

24. A*STAR, with its diverse technological capabilities (grid, cloud, security, data storage, data mining and HPC), can play a critical translational R&D role by being more involved in strategic translation or adoption initiatives (e.g. healthcare, telco, transportation). In executing these translational activities, A*STAR will also be exposed to the adoption gaps and new research opportunities.

25. A*STAR could explore opportunities in the following areas:

a. Testbed companies' specific technology needs. A*STAR could assist with companies' specific technology needs, in implementing cloud applications, with closer partnerships with IDA and EDB.

i. A key strategy is to be aggressively involved in enabling the industry through use-inspired research and industry collaboration. Strategic partnership is needed between IDA, which facilitates and encourages cloud adoption, and A*STAR, as R&D and translation enabler. IDA also provides funding for translational R&D in cloud, to incubate new technologies for deployment in e-Government and industry.

ii. In addition, A*STAR can work alongside EDB to engage and attract other promising companies to enrich the cloud ecosystem. Companies that do not have R&D presence in Singapore could benefit from R&D collaboration with A*STAR, and may potentially be encouraged to expand their operations in Singapore.

iii. To facilitate effective and fruitful engagement with IDA and EDB, SERC will appoint account managers to map out specific proactive strategies with our sister agencies to translate R&D and increase industrial partnership.

b. Focus on industry sectors. A*STAR could focus more on developing cloud related capabilities in specific sectors. Cloud is a viable solution to some of the engineering applications (such as supply chain and logistics) and biomedical applications (such as genomics IT and drug

design). These are directly relevant to some of the strategic thrusts within A*STAR. We should investigate and work on capabilities that will enable the sectors relevant to us as well.

c. Develop cloud technologies through focused R&D

i. Cloud security and privacy. Security is the foremost concern for users in transferring their companies' data to the cloud, which to some extent is due to the lack of common standards. A*STAR's competencies in areas such as security protocols, authentication and data privacy protection can contribute to R&D in data security over the cloud. I^2R could carry out more intensive R&D in this space.

ii. Storage and network technologies for big data. Data explosion compels the community to look for better technologies to handle, move and analyze big data. Service-aware, highly scalable and distributed storage and data management technologies are needed. New network technologies are essential for faster and more efficient transfer of big data in the cloud (as current solution for moving big data is still via courier service). DSI, I^2R and IHPC could team up to create new capabilities in this area.

iii. Hybrid cloud technologies. While some companies can afford to move all their IT needs to the cloud, there are many enterprises who cannot afford to do so for various reasons (such as security concerns). Hence, companies who desire to move only partial IT functions to the cloud need to worry about integration between in-house IT infrastructure and public cloud environment. Technology gaps include integration of process and data flow across infrastructure domains, and protection of sensitive in-house data. IHPC and I^2R could collaborate to tackle these issues.

iv. Service programming technologies. A*STAR could tackle sectors requiring complex, multi-disciplinary services. One technological hurdle for enterprise users is the difficulty to easily configure and use higher-level services. As cloud services are by nature dynamic and on-demand, new approaches are needed to support real-time composition and provisioning of the required complex services. The

framework also needs to consider service cost and turnaround time when handling complex services. Intuitive tools that hide the complexity of the infrastructure are required to facilitate wide adoption.

v. Services science research. Cloud is as much about the economics and business models as it is about the enabling technologies. The new paradigm requires service providers to make sense of the demands and the operations in order to stay competitive. Among the various abilities needed are: operations research, economy-based resource optimization strategies, market-oriented strategies, negotiation and pricing of services. In general, there is a lack of such research in Singapore to truly support the cloud ecosystem here. Services science research calls for the integration of multiple disciplines such as management science, decision science, economics, social science, artificial intelligence, and cognitive science. A*STAR has abundant experience in driving and leading such multi-disciplinary initiatives.

26. Cloud Technology Translation unit for complex multi-disciplinary cloud services. As a longer term strategy, A*STAR should set up a Cloud Technology Translation (CTT) unit to champion cloud adoption in specific sectors and coordinate the integration of technologies from different RIs to address multi-disciplinary needs in the enterprises. Specifically, it is recommended that the CTT unit drive a consortium comprising R&D players, industry and service providers. As IDA's translational R&D initiative strives to target specific projects, A*STAR's consortium approach should complement IDA by looking at a cohesive suite of technologies to address the end-to-end needs of a community or sector. This approach will put A*STAR in a good position to translate R&D to impact a bigger group of stakeholders.

27. As IDA and the present service providers have already taken care of Infrastructure-as-a-Service and basic enterprise needs, A*STAR should explore the other sectors such as telco, healthcare and transportation (land and air) where the solutions are likely to be more complex and multi-disciplinary. Doing so will allow A*STAR to demonstrate our multi-disciplinary assets and to establish more targeted capabilities. The CCT unit will be responsible for engaging the industry, understand the needs and identify the appropriate sector/community for the consortium to focus on.

28. With a range of expertise needed, it is probable that different RIs will champion different consortia. For instance, SIMTech may lead a manufacturing or supply-chain consortium. The CCT unit will engage appropriate RIs to identify the scope for the consortia.

29. Going forward, cloud services need a myriad of technologies to address end-to-end needs of enterprises. A*STAR's multi-disciplinary capabilities positions it to play an important role to support such industry's technology needs.

References:

1 "Effectively and Securely Using the Cloud Computing Paradigm", Peter Mell & Tim Grance, National Institute of Standards and Technology (NIST), 7 Oct 2009
2 "Gartner Says Worldwide Cloud Services Revenue Will Grow 21.3 Percent in 2009", Gartner Press Release, 26 Mar 2009
3 "Gartner identifies the top 10 strategic technologies for 2010", Gartner Press Release, 20 Oct 2009
4 "The Future of Cloud Computing", Pew Research Centre, 11 Jul 10
5 "Internet of Knowledge Implementation Approach", Infocomm Development Authority (IDA), 2009

Written by : Mr Ng Tong Jin, Asst Head (Infocomm, Media & Computing), SERC

Mr Hoang Du'c, Head (Infocomm, Media & Computing), SERC

With inputs by : Dr Terence Hung, Deputy Executive Director and Programme Manager (Advanced Computing), IHPC

Date : 20 August 2010