Chapter 12:
Green Cloud

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Outline

1.Abstract

- This chapter systematically analyze the energy consumption based on types of services and obtain the conditions to facilitate green cloud computing to save overall energy consumption in the related information communication systems.
- With a tremendously increasing number of mobile devices, green mobile communications would be the foundation of green cloud computing.

Definition of green cloud computing

- In general, cloud computing focus on the data computing efficiency; green cloud computing is a new thinking which is based on cloud computing's architecture and focuses on the energy efficiency of device and computing.

Green cloud computing

Green Cloud Computing

Cloud Computing Architecture

- Can’t Ignore Technologies
- As a Service
- Future
- Positive and Negative
- Issues
- Energy
- Goals
- Social Implications
- Network
- Sustainability Implications
- Climate Change

Green Virtual Network

- Overview of green virtual network
- Virtual network
- Virtual network architecture
- Virtual router

Toward Green Cloud Computing

- Type of Cloud Application
  - Point and Cloud
  - Point-cloud-Multipoint
  - Multipoint and Cloud
- Behavior of Contrast
  - P2P
  - MSMP
  - SSMP
- System Model
- Analysis for Type I Application
- Analysis for Type II Application
- Analysis for Type III Application
- Estimate Energy Consumption

Overview of green cloud computing

- Cloud computing may raise privacy and security concerns, but this growing practice could have one clear advantage: far energy efficiency, thanks to custom data centers now rising across the country.
- In theory, a resource like Amazon or Google's public clouds can have higher utilization and thus greater power efficiency. Locate the data center close to a green power source, like hydro plant, that can minimize transmission line power losses and be even green.

2.Cloud computing architecture

Cloud Computing Architecture

- Gartner top 10
- Cloud Computing, Today
- Future
- Issues
- Energy
- Goals
- Social Implications
- Network
- Sustainability Implications
- Green cloud?

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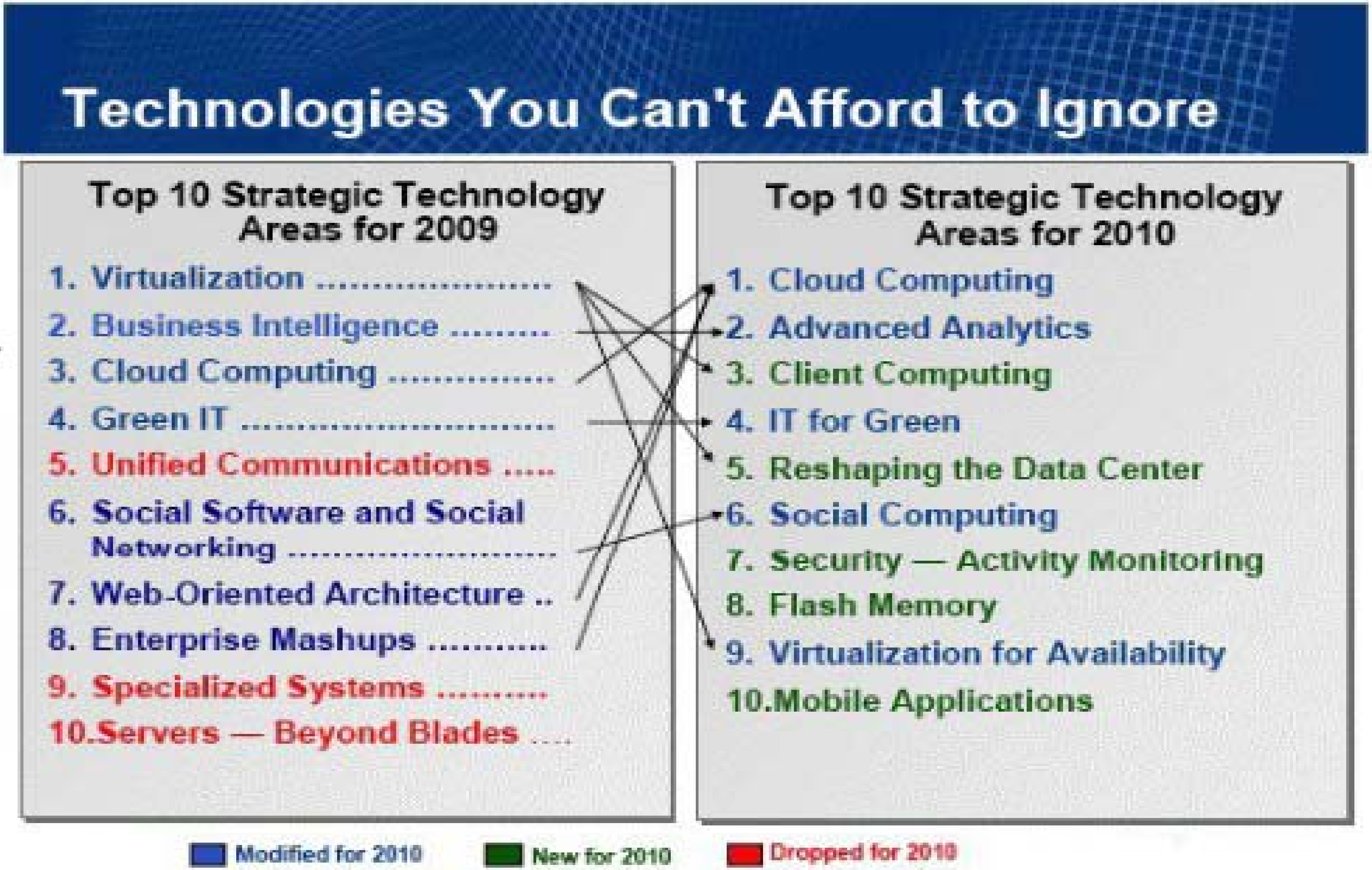
Overview of cloud computing architecture

- Cloud computing is a networked computing structure with the following features:
  - Consolidation of computing resources via virtualization;
  - Maximization of resource utilization through on-demand, real-time provisioning;
  - Delivery of computing, including applications, software, platforms, and infrastructures, as services.

Gartner top 10



src: “Green Cloud Computing”, Slidshare, Seungyun LEE

The layers of cloud computing

- A cloud computing company is any company that provides its services over the Internet. These services fall into three different categories, or layers.
- The layers of cloud computing, which sit on top of one another, are Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS) and Software-as-a-Service (SaaS).

IaaS: Infrastructure-as-a-Service

- The first major layer is Infrastructure-as-a-Service, or IaaS. (Sometimes it's called Hardware-as-a-Service.)
- Several years back, if you wanted to run business applications in your office and control your company's website, you would buy servers and other pricy hardware in order to control local applications and make your business run smoothly.
- But now, with IaaS, you can outsource your hardware needs to someone else. IaaS companies provide off-site server, storage, and networking hardware, which you rent and access over the Internet.
- Freed from maintenance costs and wasted office space, companies can run their applications on this hardware and access it anytime.

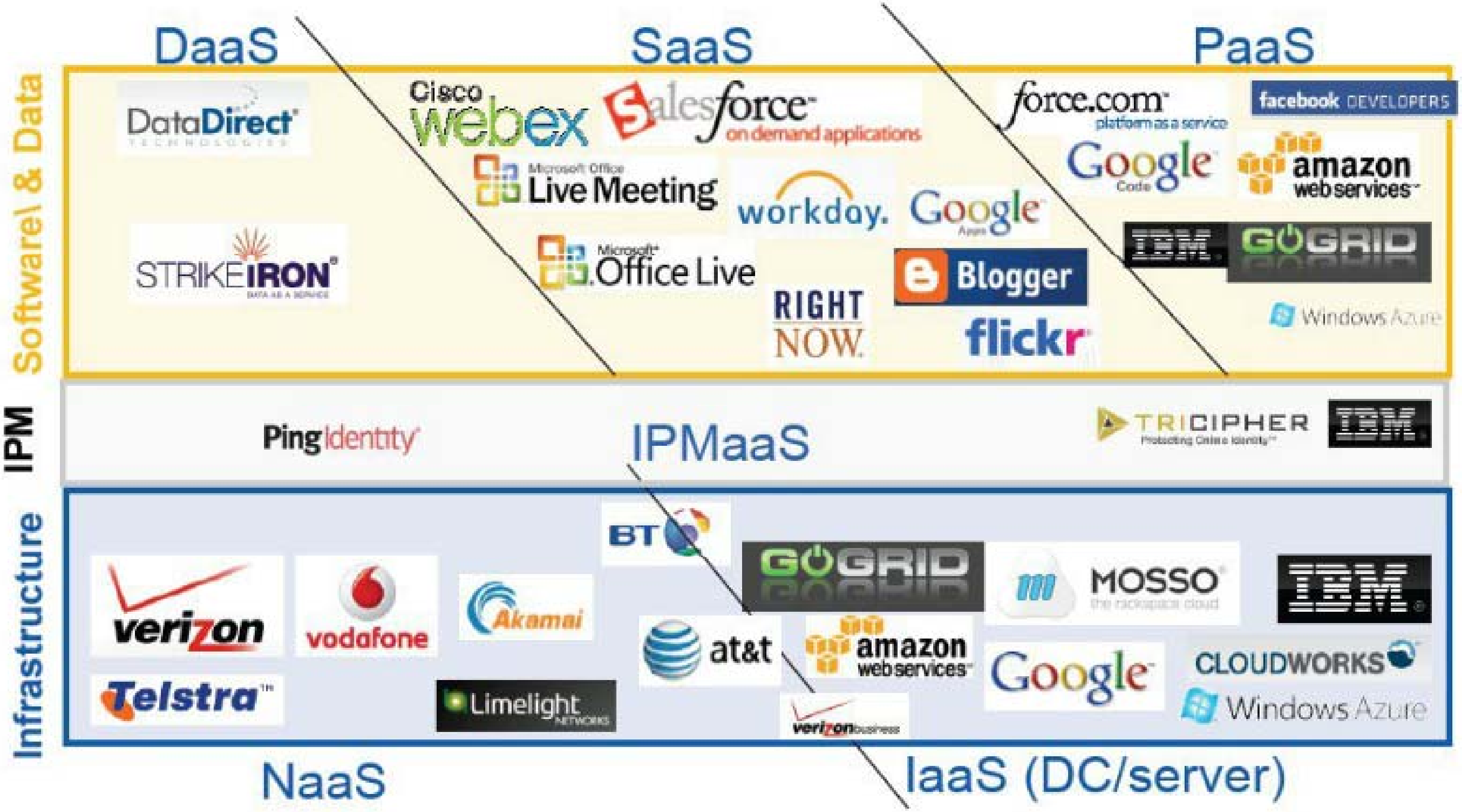
PaaS: Platform-as-a-Service

- The second major layer of the cloud is known as Platform-as-a-Service, or PaaS, which is sometimes called middleware.
- The underlying idea of this category is that all of your company's development can happen at this layer, saving you time and resources.
- PaaS companies offer up a wide variety of solutions for developing and deploying applications over the Internet, such as virtualized servers and operating systems.
- This saves you money on hardware and also makes collaboration easier for a scattered workforce.
- Web application management, application design, app hosting, storage, security, and app development collaboration tools all fall into this category.

SaaS: Software-as-a-Service

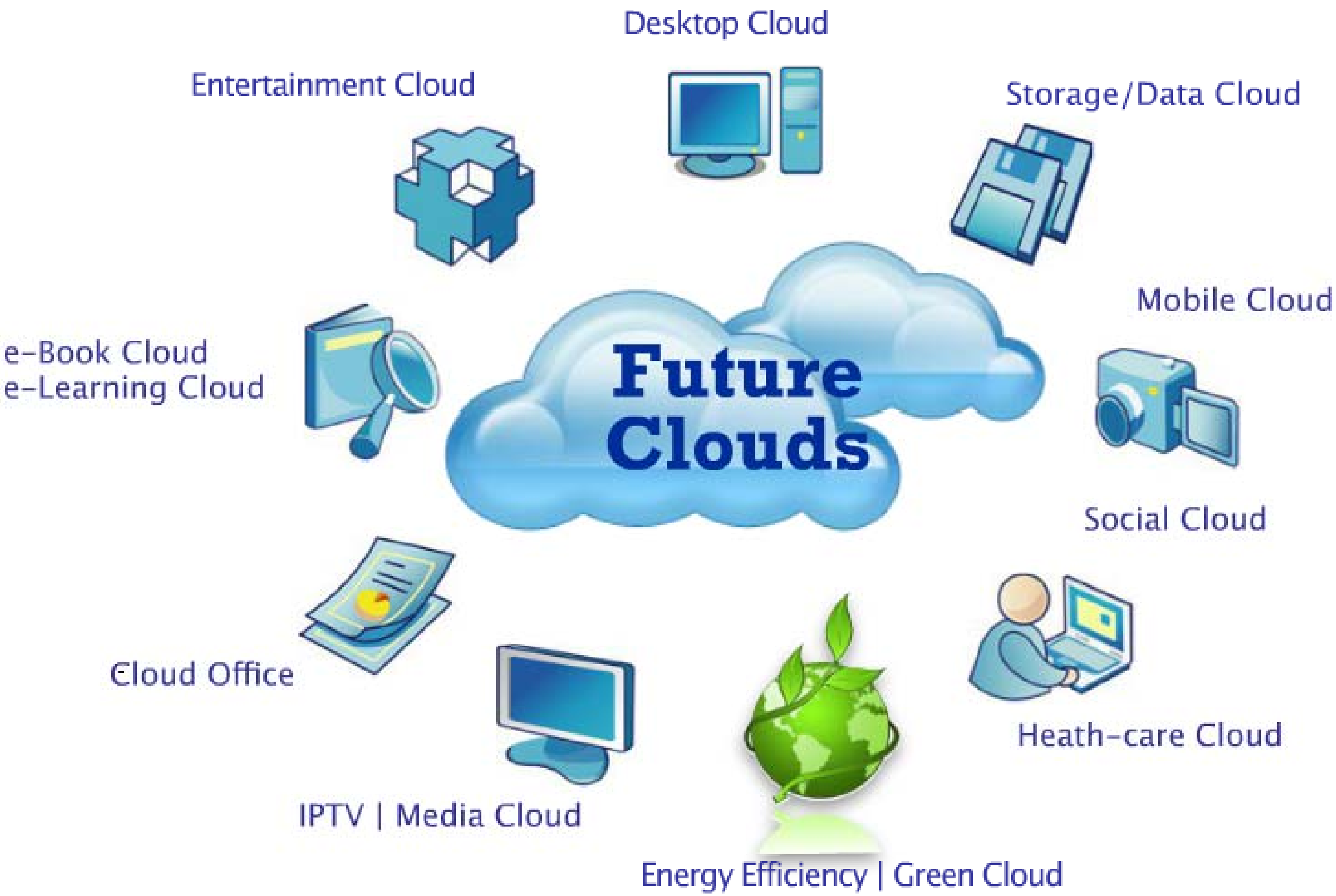
- The third and final layer of the cloud is Software-as-a-Service, or SaaS.
- This layer is the one you're most likely to interact with in your everyday life, and it is almost always accessible through a web browser.
- Any application hosted on a remote server that can be accessed over the Internet is considered a SaaS.
- Services that you consume completely from the web like Netflix, MOG, Google Apps, Box.net, Dropbox and Apple's new iCloud fall into this category.
- Regardless if these web services are used for business, pleasure or both, they're all technically part of the cloud.

Cloud Computing, Today



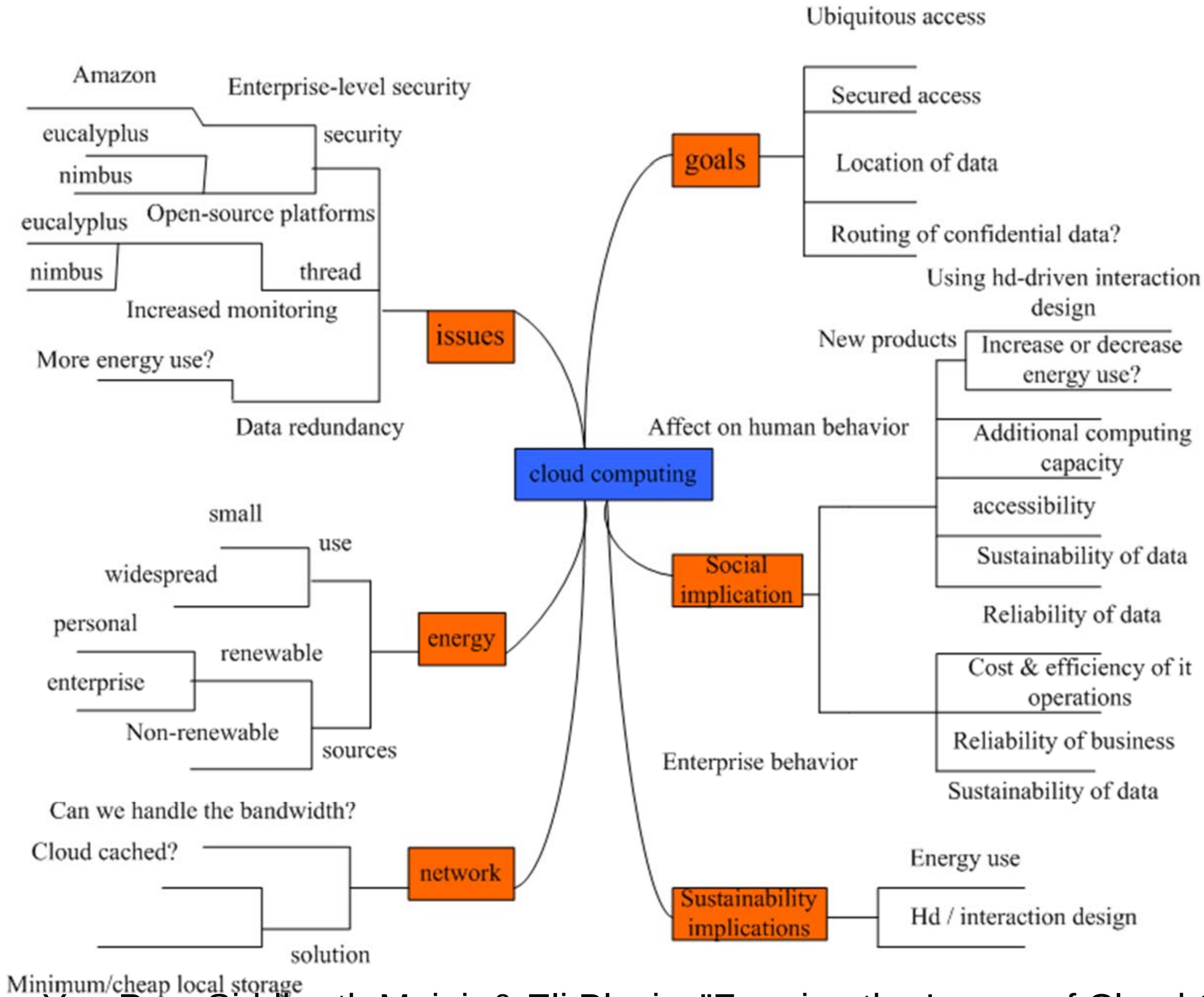
src: “Green Cloud Computing”, Slidshare, Seungyun LEE

Future clouds



src: “Green Cloud Computing”, Slidshare, Seungyun LEE

Cloud computing architecture



src: Yue Pan, Siddharth Maini, & Eli Blevis, "Framing the Issues of Cloud Computing & Sustainability: A Design Perspective" IEEE International Conference on Cloud Computing Technology and Science

Green cloud?

Positive	Negative
• Datacentres can become the most efficient centres for computation yet • Providers will want to increase cost effectiveness and be green!	• Datacentres are now consuming 0.5% of all electricity in the world. • This will only continue to grows!

src: “Energy Aware Clouds”, Slidshare, James W.Smith

3.Toward green cloud computing

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Architecture Cloud Computing

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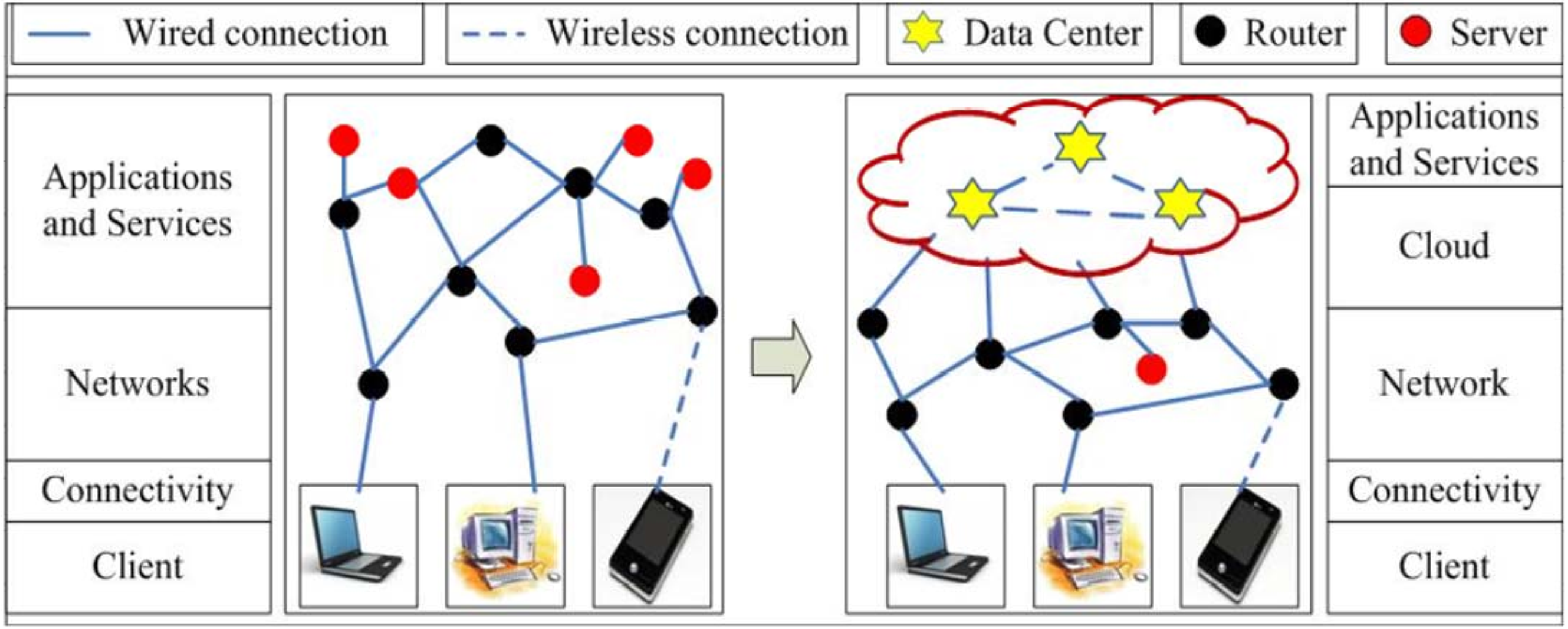
Overview of toward green cloud computing

- Among all industries, the information communication technology (ICT) industry is arguably responsible for a large portion of the world-wide growth in energy consumption.
- This is partly attributed to the rapidly increasing number of Internet and mobile ICT devices available across the globe.
- As Internet has penetrated into our daily lives, cloud computing has emerged as a new kind of "utility" that gets delivered through wired or wireless networks
- Although it is widely claimed that cloud computing is "green" because of its better energy efficiency, we are going to examine this thesis more carefully via an analytic approach in this chapter.

Fig. 1: Toward green cloud computing architecture



src: "Toward green cloud computing", National Taiwan University, Taipei, Taiwan ICUIMC '11

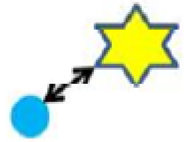
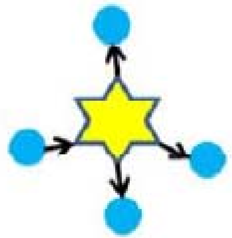
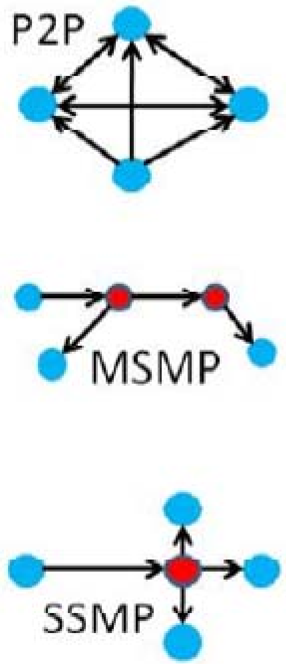
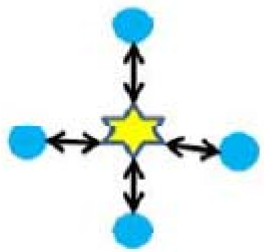
Toward green cloud computing architecture (cont.)

- Fig. 1 shows the difference in networking infrastructure brought by cloud computing.
- The system-wide energy consumption is the sum of energy consumed by all ICT devices involved in the system, which we classify into three categories according to their functionality.
  - Personal terminals: all kinds of personal application devices such as desktop computers, laptop computers, handsets, etc.
  - Networking nodes: communication and networking devices that facilitate connectivity from devices to the cloud, such as routers, switches, hubs, access points, etc.
  - Local servers: the equipment to provide services to personal terminals, such as application servers.

Categorization of cloud applications

- Based on traffic patterns, we classify applications into three categories as follows:
  - Point and Cloud (Type I): applications that need only communication between user and the cloud. Examples include Dropbox, Remote Desktop, etc.
  - Point-Cloud-Multipoint (Type II): applications in which traffic is initiated from one user to one or more other users through the cloud. Examples include Gmail, Skype, YouTube, etc.
  - Multipoint and Cloud (Type III): applications that provide a platform for users to cooperate on a common piece of work. A good example is Google Docs.

Fig. 2: Categorization of cloud applications

Type of Cloud Application	Behavior	Behavior of Contrast App.
I. Point and Cloud (Ex: office, disk,…)		
II. Point-Cloud-Multipoint (Ex: Gmail, Youtube,…)		
III. Multipoint and Cloud (Ex: Google doc.,…)		

Categorization of cloud applications

- The three types of applications are summarized in Figure 2, blue and red circles denote personal terminals and local servers, respectively, and yellow stars are data centers in the cloud. The black arrows represents communication links, which also show the direction of information flows.
- The amount of energy consumed by each type of devices depend heavily on user behavior, which is different with and without the cloud.

Categorization of cloud applications

- In Figure 2, we also list the corresponding contrast applications that can run without the cloud.
- Obviously, Type I applications are to replace applications on personal terminals, so the contrast applications are those which run completely on personal terminals without communicating with others, e.g., desktop office software.
- On the other hand, both Type II and Type III applications are to replace client-server or other type of applications that involve some communication.

The three types of contrast applications

- P2P (point-to-point): applications that communicate with each other directly, e.g., BitTorrent.
- MSMP (multi-server, multi-point): applications that communicate via multiple servers, e.g., email.
- SSMP (single-server, multi-point): applications that provide a central resource repository, e.g., file transfer.

System model notation

$\triangle E(comm)$	Without cloud computing's architecture communication energy consumption
$\triangle E(comp)$	without cloud computing's architecture computing energy consumption
L_p	Categories of personal terminals
L_s	Categories of network nodes
L_n	Categories of servers
α	Belong personal terminals, network nodes and servers
$N(l_p)$	The number of devices in the l_p-th category of personal terminals
$E_{tx}(l_p)$	Within a period D, the energy for transmitting one bit by the communication circuitry of in the l_p-th category
$E_{cir}(l_p)$	Within a period D, the energy consumed by the communication circuitry of device in the l_p-th category
$T_m(l_p)$	The numbers of bits transmitted for device m for personal terminals

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System model

- Assuming there are L_p categories of personal terminals, L_n categories of network nodes, and L_s categories of servers. The number of devices in the l_p -th category of personal terminals is denoted as $N(l_p)$; similarly, we have $N(l_n)$ and $N(l_s)$ for network nodes and servers, respectively.
- Then, the overall difference in communication energy consumption can be expressed as:

$$\Delta E(comm) = \Delta\left\{ \sum_{\alpha\in\{p,n,s\}} \sum_{l\alpha=1}^{L\alpha} \sum_{m=1}^{N(l\alpha)} [T_m(l_\alpha)E_{tx}(l_\alpha) + E_{cir}(l_\alpha)] \right.$$

$$\Delta E(comp) = \Delta\left\{ \sum_{\alpha\in\{p,s\}} \sum_{l\alpha=1}^{L\alpha} N(l_\alpha)E_{comp}(l_\alpha) \right\}$$

System model(cont.)

- $\triangle E(comm)$ 是沒有雲端通訊消耗的能量。
- $\triangle E(comp)$ 是沒有雲端計算消耗的能量。
- $E(cloud)$ 操作雲端所需要的能量。
- $E(cloud) < |\triangle E(comm)| + |\triangle E(comp)|$ 所以雲端操作的能量小於通訊加上計算消耗的能量才符合綠色。

Estimate energy consumption

- Communication energy:
  - $E_{tx}(L_p = 1) = E_{tx}(L_s = 1)$: 8.5*10^{-9} joule/bit 8.5*10^{-9}
  - $E_{cir}(L_p = 1) = E_{cir}(L_s = 1)$: 24480 joule/day
  - $E_{tx}(L_n)$: 2.7*10^{-11} joule/kilometer/bit
- Computation energy
  - $\triangle E(comp)(l_s)$: 7*10^{7} joule/day
  - $\triangle E(comp)(l_p = 1)$: 5.76*10^{6} joule/day
- Cloud operation energy: the estimated energy consumption of a data center is 4*10^{11} joule/day.

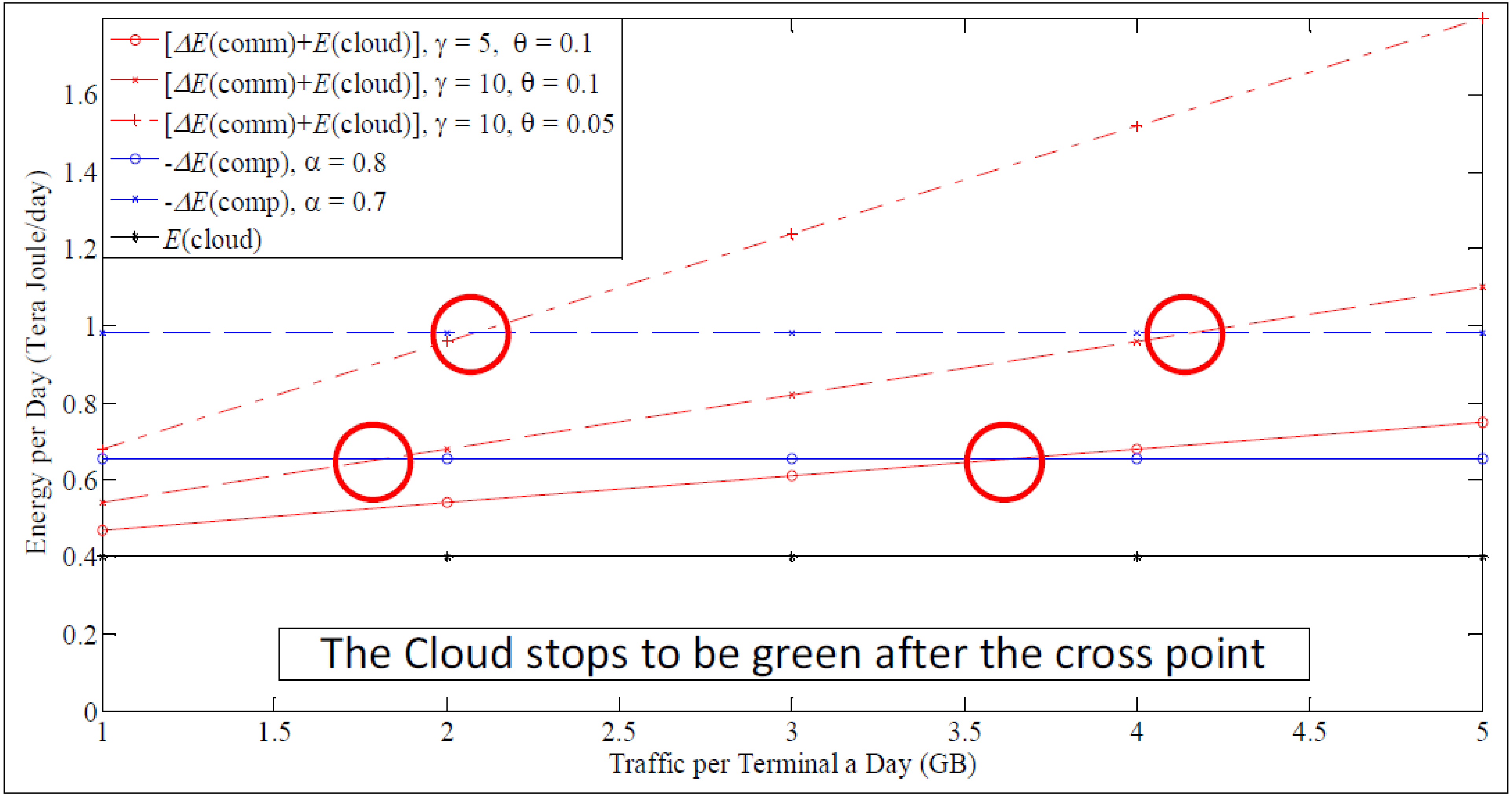
Energy usage of a 5,000-sq-ft data center

Category	Power drawn
Computing	588 kW
UPS and distribution losses	72 kW
Cooling for computing and UPS losses	429 kW
MV transformer/others	38 kW
Total	1127 kW

Energy analysis notation

α	Represents then energy saved when personal terminals offload their computation to the cloud
β	The power saving for each server
γ	The number of bits generated in the network per data bit
θ	The performance degradation ratio for wired and wireless access at personal terminal

Fig. 3: Energy analysis for type I applications



src: "Toward green cloud computing", National Taiwan University, Taipei, Taiwan ICUIMC '11

Energy analysis for type I applications

- Taking into accounts the cloud operating energy $E(cloud)$, the condition that the overall energy consumption can be reduced can be expressed as:

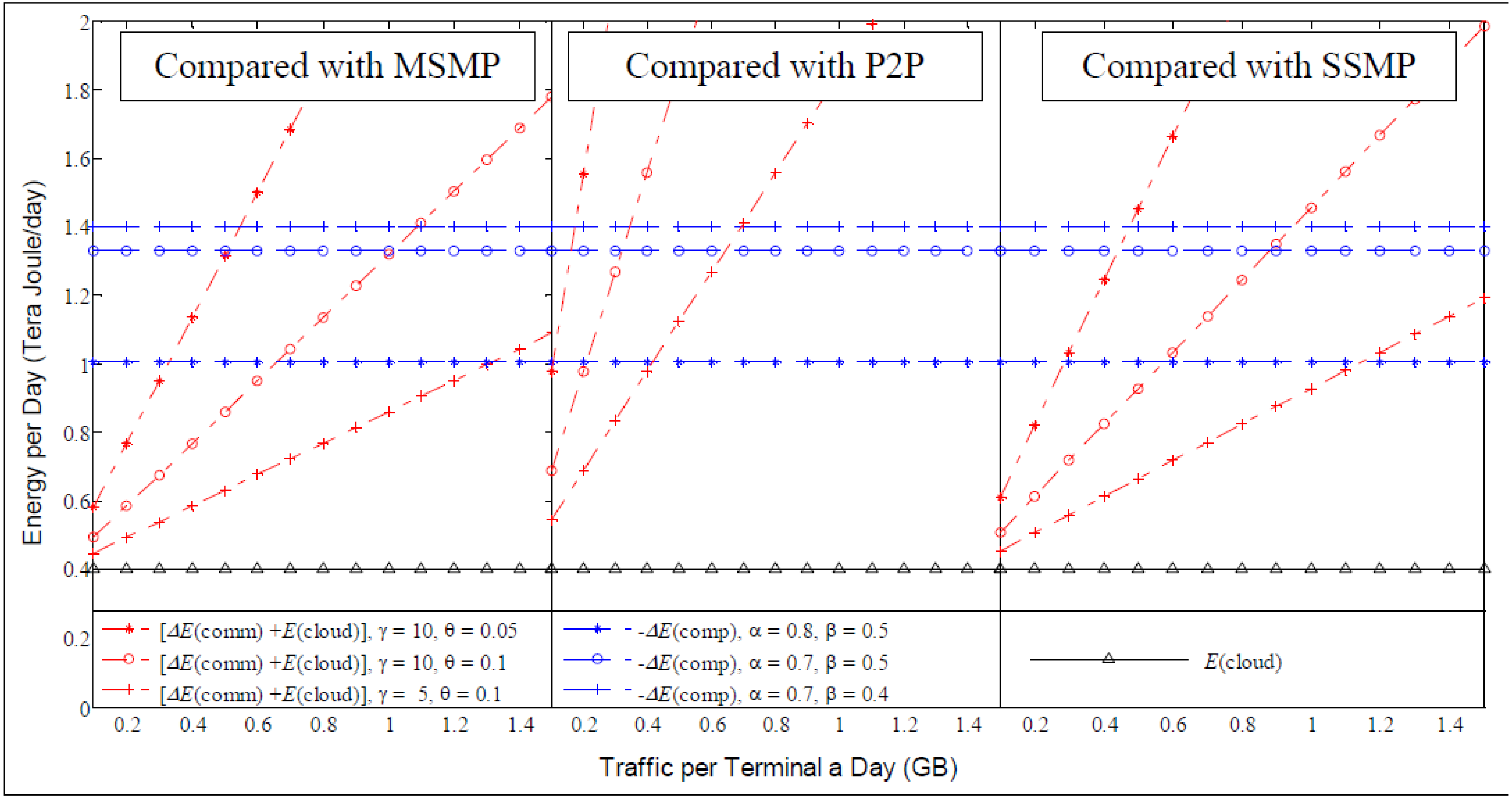
$$\triangle E(comm) + E(cloud) < |\triangle E(comp)|$$

- To better understand the effect of the new traffic, we plot the induced communication energy with traffic due to Type I applications in Figure 3.

The observations of Type I in figure 3

- Unlimited traffic would offset, suggesting that data compression and efficient management to reduce traffic is vital to green cloud computing.
- Inefficiency of wired and wireless access significantly increases the energy cost per bit transmitted, suggesting that effective transmission scheme and updated communication infrastructure is vital to green cloud computing.
- It is critical to develop smart traffic routing algorithms in wired and wireless networks in order to reduce traffic overhead that wastes transmission power.

Fig. 4: Energy analysis for type II applications



src: "Toward green cloud computing", National Taiwan University, Taipei, Taiwan ICUIMC '11

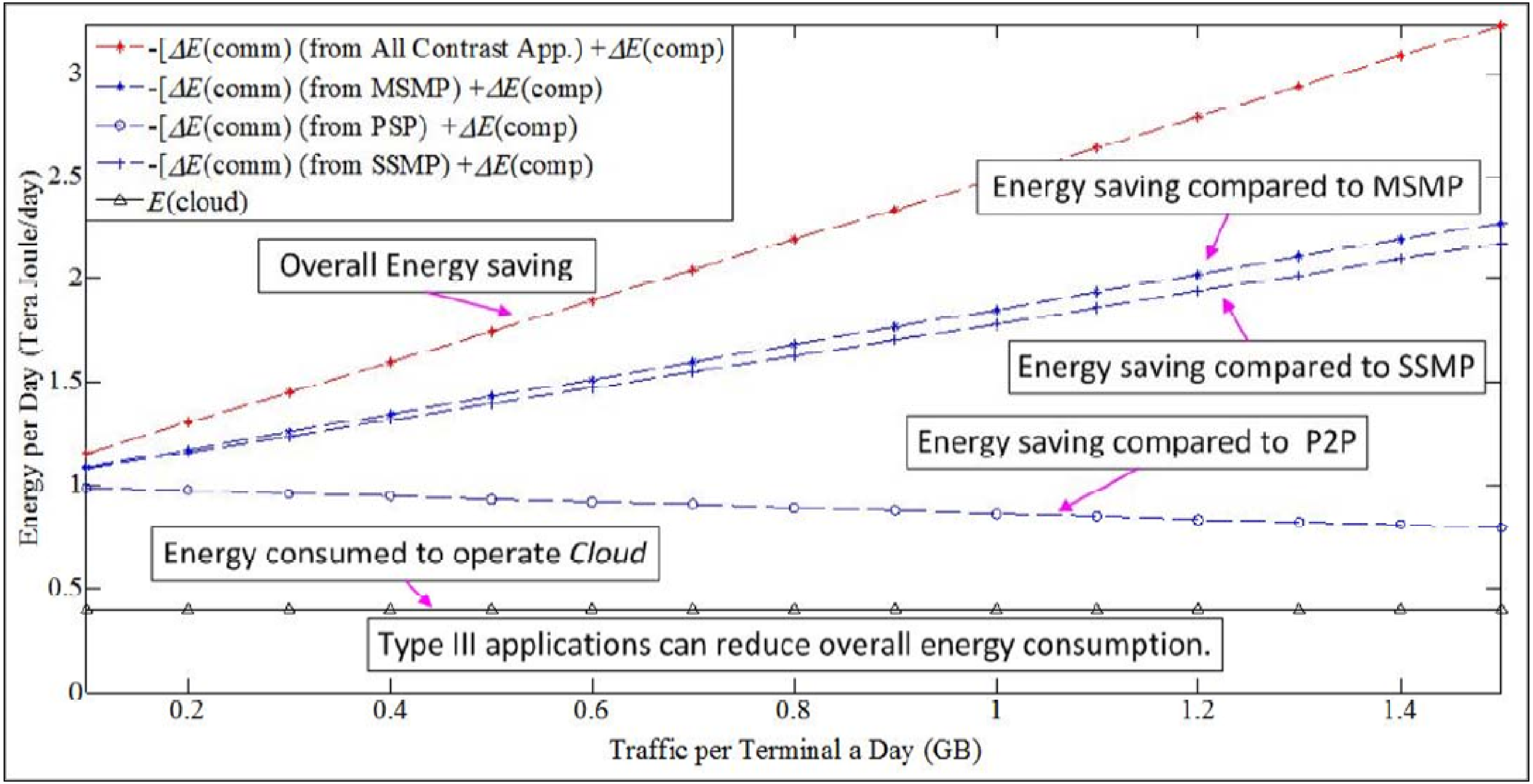
Energy analysis for type II applications (cont.)

- The main effect of Type II applications on networking and connectivity is to the changed routing of traffic from local servers to remote servers in the cloud.
- Therefore, the communication energy of personal terminals is expected to be invariant, while the communication energy of networking nodes are expected to increase.
- Furthermore, the computation energy consumption on personal terminals and local servers also decreases, as the tasks are offloaded to the cloud.
- Thus, the increased communication energy consumption due to routing changes needs to be compensated by the net energy saving of moving computation from personal terminals and local servers to the cloud after taking the cloud's fixed operation energy consumption into accounts.

The observations of Type II in figure 4

- The increased communication energy consumption due to traffic redirection from local to remote servers in the cloud would eventually offset any benefits of computation offloading, no matter compared with MSMP, P2P, or SSMP.
- The computation energy saving from personal terminals is larger than from local server because there are much more personal terminals than local servers.

Fig. 5: Energy analysis for type III applications



src: “Toward green cloud computing”, National Taiwan University, Taipei, Taiwan ICUIMC '11

Energy analysis for type III applications

- Type III applications also change traffic routing from local to remote server in the cloud.
- The major difference between Type III and Type II applications is that the former provides a platform for users to collaborate on a common task such that instead of the whole data, every user only needs to access the portion that he or she needs to complete his or her part of the work.
- Thus, the condition under which the cloud computing is green becomes:

$$E(cloud) < |\triangle E(comp)| + |\triangle E(comm)|$$

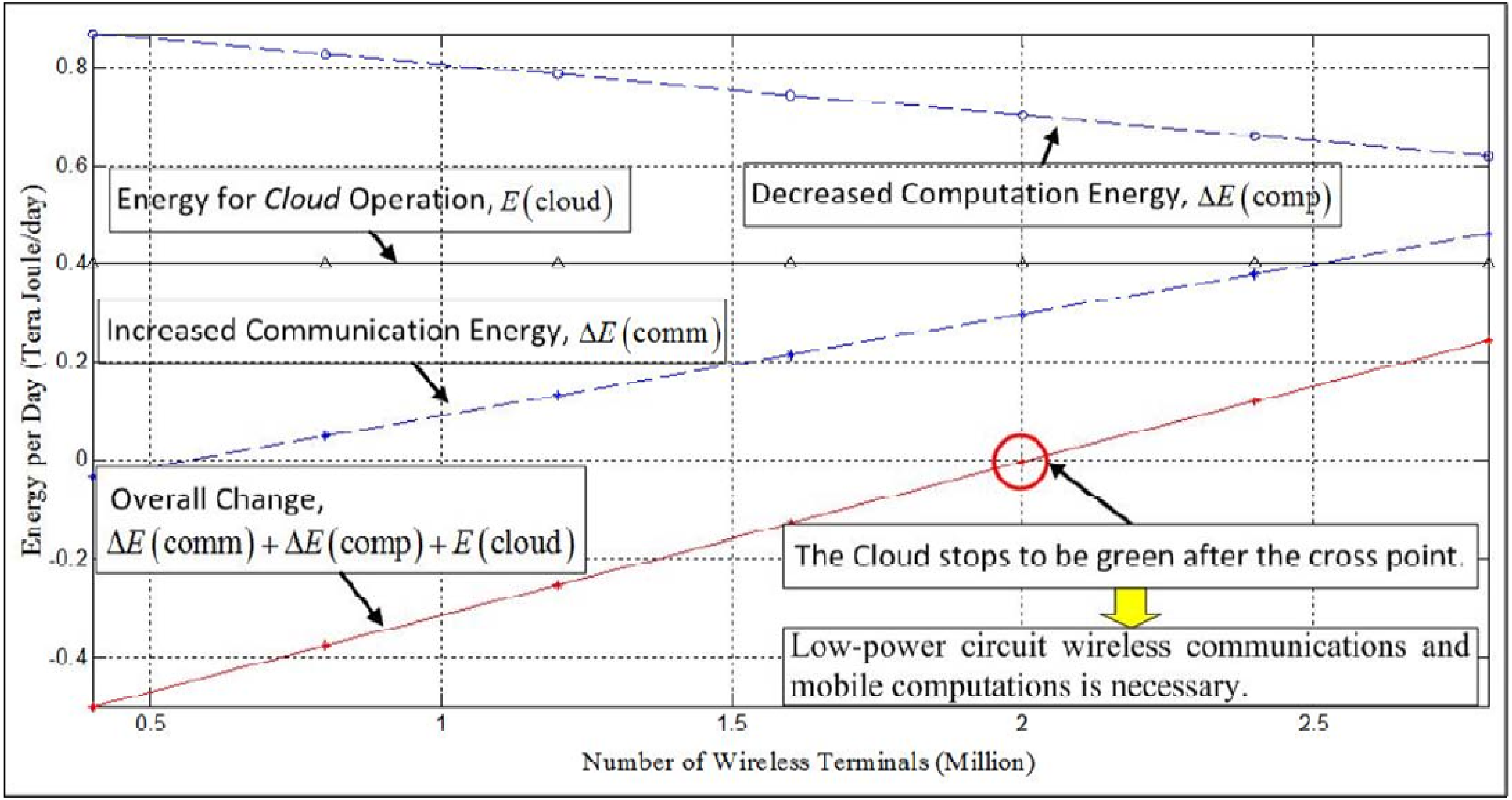
The observations of Type III in figure 5

- We can observe that the saved computation and communication energy is in general larger than the energy cost to operate the cloud.
- Although the energy saving from P2P decreases with traffic, the total energy saving from all contrast applications increases with traffic.
- Therefore, Type III applications can indeed effectively reduce overall system-wide energy consumption.

Effect of increasing terminals

- One major factor for increased ICT energy consumption is the exponentially growing number of terminals, a phenomenon known as the network effect.
- Such an increasing number of terminals would not only increase the communication energy but also decrease the computation energy saving from existing terminals and servers.

Fig. 6: Effect of increasing terminals

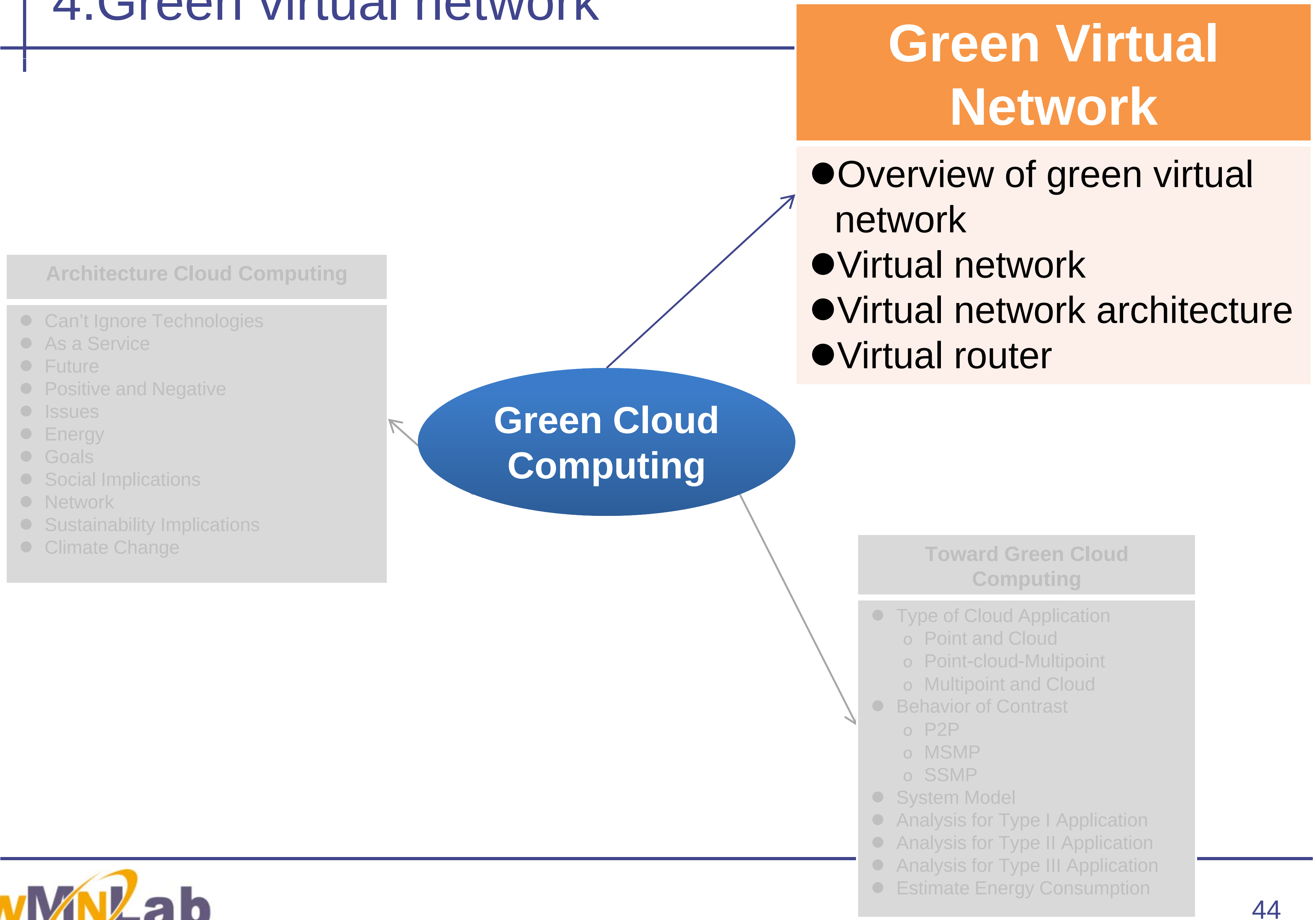


src: "Toward green cloud computing", National Taiwan University, Taipei, Taiwan ICUIMC '11

Effect of increasing terminals (cont.)

- Figure 6 plots the trend of communication energy consumption increasing and computation energy consumption decreasing as the number of wireless terminals increases, taking into accounts the cloud operation energy consumption.
- As long as the per-terminal computation energy saving is smaller than communication energy consumption, the cloud computing can not support indefinitely many terminals in an energy efficient manner.

4.Green virtual network



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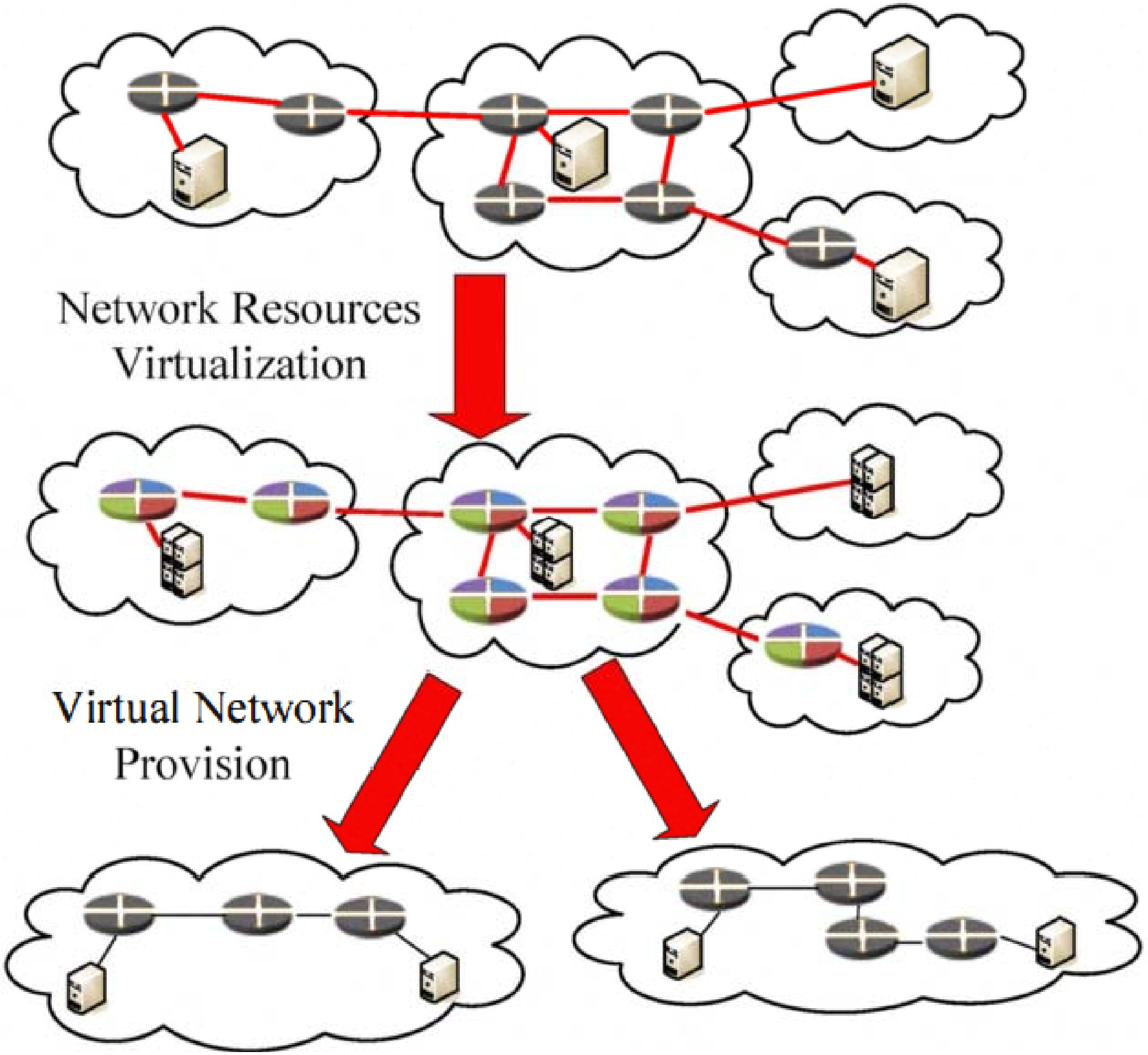
Overview of green virtual network

- This chapter propose a virtual network architecture for cloud computing. Virtual network can provide communications for virtual resources in cloud computing.

Virtual network

- Firstly, the network components such as the link, the switch, and router have to be virtualized.
- Tunneling is a technique to implement virtual links. And a soft router is used to implement the virtual router.
- When users make a demand, a customized virtual network will be provided.
- The virtual network provision is a critical step, since it needs to satisfy the requirements of users.

Fig. 7: Virtual network (cont.)

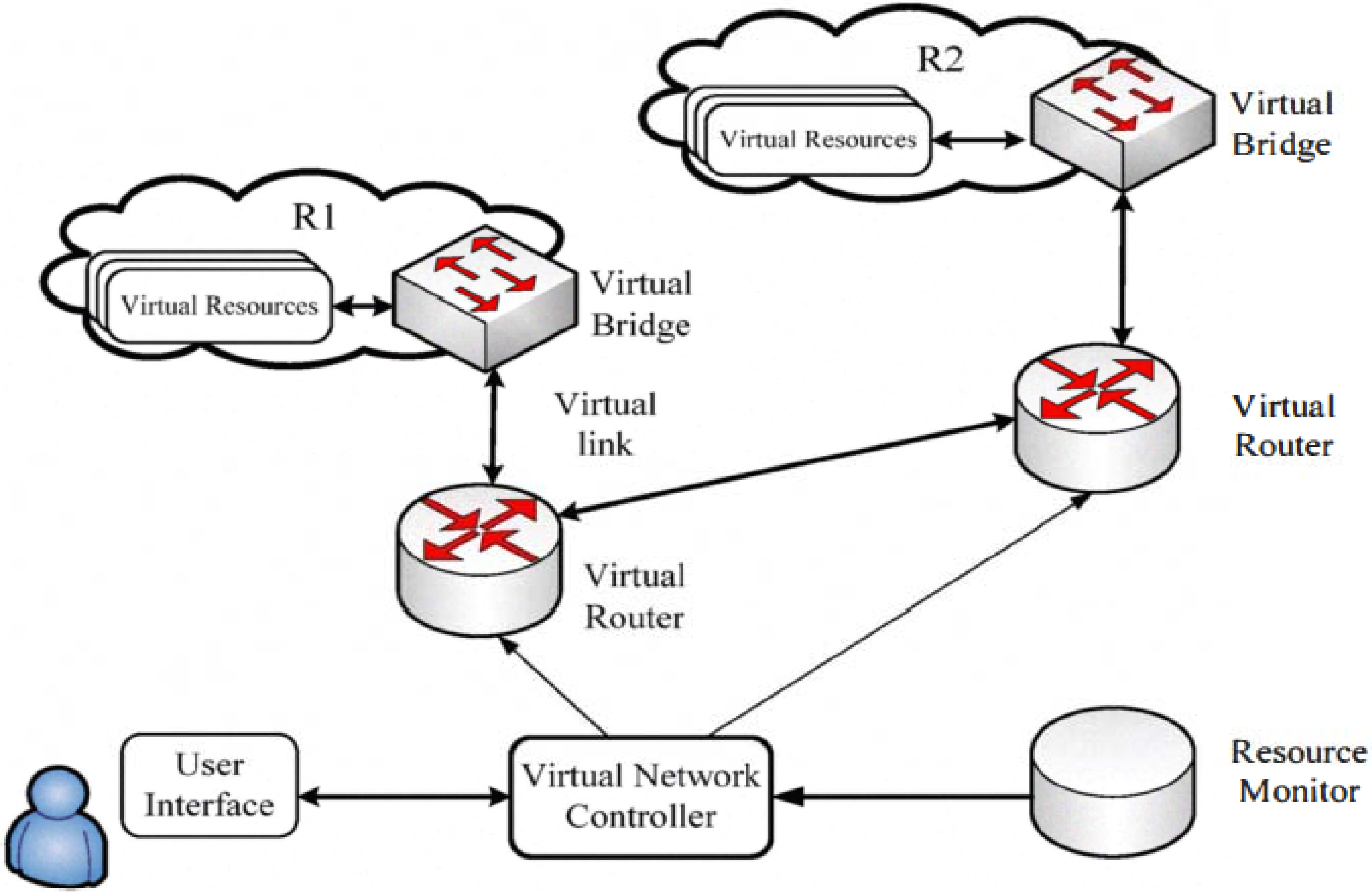


src: "Green Virtual Networks for Cloud Computing" ICST

Virtual network architecture

- We use a hierarchical structure to build the virtual network for facilitating management.
- In Figure 7, the virtual resource uses virtual links to connect to the virtual bridge.
- The virtual bridge can increase flexibility and transferring speed in the virtual network.
- The virtual bridge provides the interface and forwards packets for the virtual resources that connect to it.
- The virtual bridge decreases the loading of the virtual router.
- The virtual router forwards packets to the destination.

Fig. 8: Virtual network architecture (cont.)

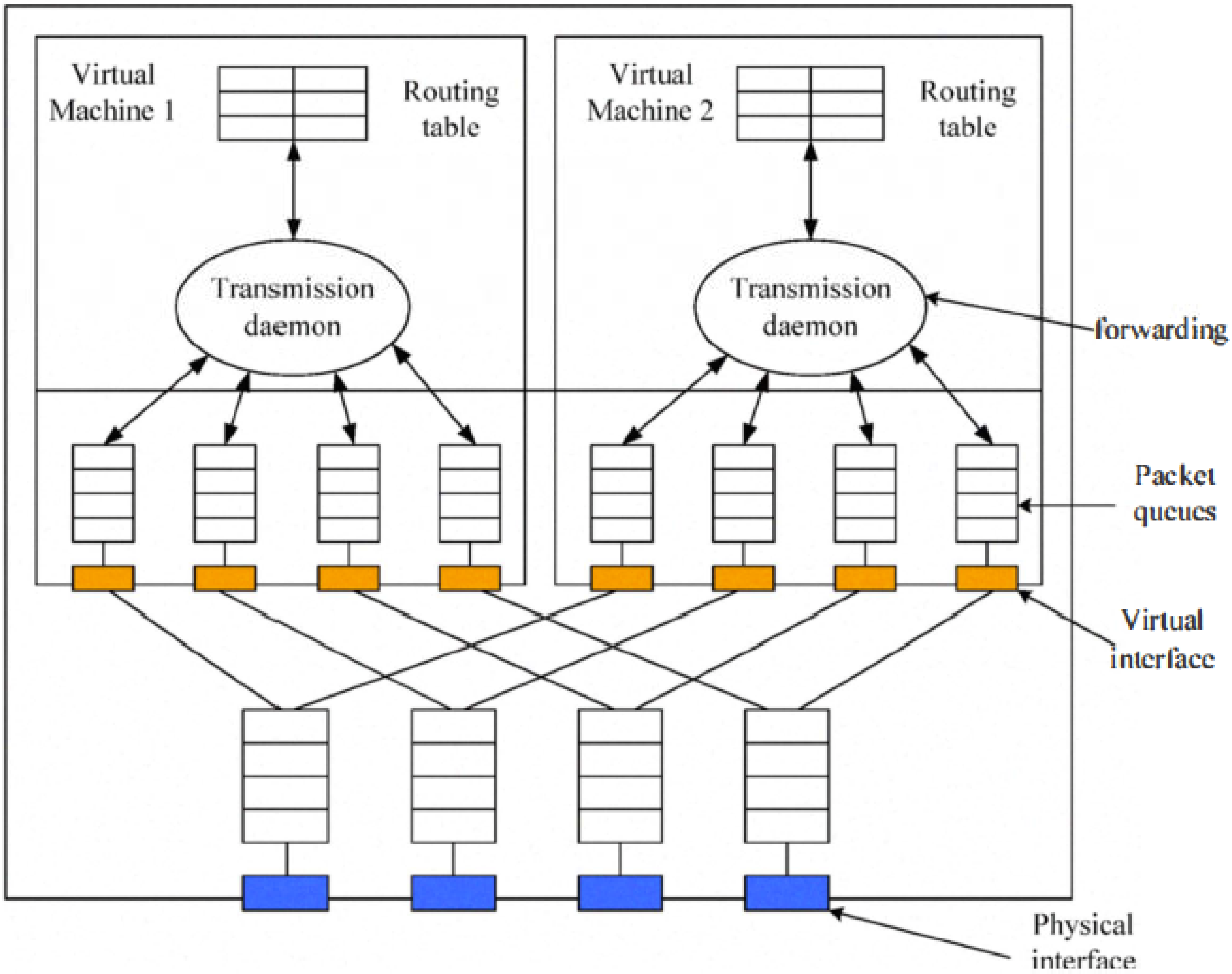


src: "Green Virtual Networks for Cloud Computing" ICST

Virtual router

- Each virtual router is composed of the routing table,
- transmission daemon, and the virtual interface.
- The transmission daemon runs the customized routing algorithm.
- Virtual interfaces share the physical interface.
- In the computer with the multi-core CPU, the instruction parallelism profoundly affects the performance of the virtual router.

Virtual router (cont.)



src: "Green Virtual Networks for Cloud Computing" ICST

5.Conclusion

- As cloud computing becomes more wide-spread, energy efficiency will become more important. The green virtual network architecture proposed in this paper is just a beginning. More research needs to be done to make it more efficient and to measure the actual performances.

6.Reference

1. Seungyun LEE, “Green Cloud Computing”, Slidshare
2. James W.Smith, “Energy Aware Clouds”, Slidshare
3. Yue Pan, Siddharth Maini, & Eli Blevis, ”Framing the Issues of Cloud Computing & Sustainability: A Design Perspective” IEEE International Conference on Cloud Computing Technology and Science
4. James W.Smith, “Energy Aware Clouds”, Slidshare
5. “Toward green cloud computing”, National Taiwan University, Taipei, Taiwan ICUIMC '11
6. “Green Virtual Networks for Cloud Computing” ICST

Homework #12:

1. Describe the positive and negative impacts of datacenter to green cloud computing.
2. Describe three types of cloud applications.
3. Describe the virtual network architecture.