Course: Cloud Computing

Week11: Mobile Cloud Computing

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Lecture Learning outcome

- At the end of this lesson, you will be able to;
- Understand Mobile computing
- Understand Global System for Mobile Communications
- Understand mobile computer architecture
- Understand Mobile cloud computing
- Understand Mobile Edge computing

Introduction to Mobile Computing

- Mobile computing refers the computational tasks performed by a mobile user using his smart phone. The smart phone handsets usually have very limited processing power and memory and have limited capacity to handle heavy weight computational tasks.
- Mobile computing systems are computing systems that may be easily moved physically and whose computing capabilities may be used while they are being moved. Examples are laptops, personal digital assistants (PDAs), and mobile phones.

GSM (Global System for Mobile Communications)

- Is a globally acceptable standard for digital cellular communication, they provide greater subscriber capabilities than analogue systems.
- **Features extended by mobile network operators using GSM;**
- **Voice Calls**: Users have the privileges of making and receiving phone calls any time because GSM networks support voice calls.
- **Short Message Service (SMS)**: The SMS have made communication cheap and easy, the user is able to send a text message, usually not exceeding 160 characters to other mobile phone users.

GSM (Global System for Mobile Communications

- **Multimedia Messaging Service (MMS)**: Multimedia content such as pictures, videos, audio files, and text can be sent from one mobile device to other mobile phones or email addresses.
- **Call Waiting**: A user can receive incoming calls, while having his or her phone engaged in another call. The user is notified of the incoming call and can choose to answer the call by putting the current call on hold, or reject the incoming call.
- **Call Forwarding**: Call forwarding enables users to redirect incoming calls to another phone number or voicemail when they are unable to answer the call on their mobile phone.

GSM (Global System for Mobile Communications

- **Call Barring**: In Call barring, users are able to filter out calls by restricting certain types of outgoing or incoming calls, such as international calls, premium-rate numbers, or calls to specific numbers or services.
- **International Roaming**: GSM networks support international roaming, allowing subscribers to use their mobile phones and access GSM services while traveling abroad. Roaming agreements between operators enable seamless connectivity in foreign networks, albeit often at additional costs.

GSM (Global System for Mobile Communications

- **Value-Added Services**: Mobile network providers offer a number of value-added services such as social chats, mobile banking, mobile payments, content subscriptions, location-based services, and personalized ring back tones.
- **Data Services**: GSM networks provide data services for accessing the internet, sending and receiving emails, browsing websites, and using mobile apps. Data services may be provided via GPRS (General Packet Radio Service), EDGE (Enhanced Data Rates for GSM Evolution), or newer technologies like 3G, 4G LTE, and 5G.

GSM (Global System for Mobile Communications

- **Voicemail**: Voicemail is an electronically stored voice message that is left by a caller to be retrieved later by the intended recipient through their mobile device. GSM networks offer voicemail services, allowing callers to leave voice messages when the called party is unavailable. Subscribers can retrieve and manage their voicemail messages from their mobile phones.
- **Caller ID**: GSM networks enable users to see the number of the incoming calls on their mobile phone screen (caller identification).

Wireless communication systems

- A wireless communication system is built from various types of basic components which include;
- **Transmitter**: The input to a wireless transmitter may be voice, video, data or other types of signal that is meant to be transmitted to one or more distant receivers. This signal is called the base band signal. Transmitter is response for modulating or encoding several base bands.

Wireless communication systems

- **Receiver:** The receiver receives modulated signals and reverses the functions of the transmitter component and thereby recovers the transmitted base band signal. The antenna of the receiver is capable of receiving the electromagnetic waves radiated from many sources over a relatively broad frequency range
- **Filters:** They are used to reject interfering signals lying outside the operating band of receivers and transmitters

Wireless communication systems

- **Antenna:** The functions of an antenna are to convert electric signal from a transmitter to a propagating electromagnetic. In a transceiver, a transmitter and a receiver are co-located from supporting full duplex communications.
- **Amplifiers:** Increases the strength of a signal. Important specifications of an amplifiers are power gain and the noise figure
- **Mixers:** A mixer is typically used to achieve frequency conversion at the transmitters and receivers, frequency conversation enables signals to be transmitted at higher frequency

Mobile telecommunication system

- The architecture has three main components which include: The CORE Network, The radio access network, and the mobile phone
- **Radio Access Network**
- Mobile devices communicate over the radio access network, which is composed of the base stations that communicate with mobile phones using radio frequency electromagnetic waves; the coverage area is structured into hexagonal cells. In each cell a base station is located

Core Network

- The CORE network interconnects the base stations, the mobile switching center and also provides an interface to other networks such as traditional telephone network and the internet. The interconnect used in the Core network is required to provide high- speed connectivity. Fiber optic cables are usually used as the backbone-inter-connect in the core network.

Mobile computing Architecture

- **Mobile Devices**: All devices used in mobile computing for instance PDA, Smartphones, iPad, tablets, wearable, laptops and all other portable devices with processors, memory, storage, sensors, and communication modules (e.g., Wi-Fi, Bluetooth, cellular).
- **Application Development Frameworks**: Tools like Android SDK (for Android) or iOS SDK (for iOS) are used to create mobile applications. These frameworks provide APIs (Application Programming Interfaces) and tools for building, testing, and deploying apps.

Mobile computing Architecture

- **Mobile Networks**: All Mobile computing devices use wireless networks for communication and accessing data. These networks include cellular networks (e.g., 4G LTE, 5G), Wi-Fi, Bluetooth, and NFC (Near Field Communication). Mobile devices can switch between different networks based on availability and user preferences.
- **Operating System (OS)**: Mobile devices are supported by operating systems that are customized to suit them, these operating systems support installations and program execution in the mobile devices, the operating system also has a friendly user interface, examples of operating systems include black berry, Symbian, Android, iOS, or Windows Mobile.

Mobile computing Architecture

- **Mobile Applications**: They can be pre-installed by the device manufacturer or downloaded from app stores. Applications can range from productivity tools, games, social media platforms, to specialized business applications.
- **Cloud Services**: Many mobile applications rely on cloud services;
- Software-as-a-service (SaaS): Licenses are given on a pay-as-you-go or on-request basis. SaaS applications include Big-Commerce, Google Apps, Salesforce, Dropbox, MailChimp, ZenDesk, DocuSign, Slack, and Hubspot, among others.

Mobile computing Architecture

- Infrastructure-as-a-service (IaaS): Delivery of everything like working frameworks to servers and storage as part of an on-demand service using IP-based availability. IaaS providers include Digital-Ocean, Linode, Rackspace, Amazon Web Services (AWS), Cisco Metapod, Microsoft Azure, and Google Compute Engine (GCE).

Mobile computing Architecture

- Platform-as-a-service (PaaS): PaaS shares some similarities with SaaS, the main difference being that instead of delivering programming over the Internet, it is a platform for creating programming that is delivered over the Internet. Platforms like Salesforce.com and Heroku are used in this model. PaaS services include Salesforce Heroku, AWS Elastic Beanstalk, Microsoft Azure, and Engine Yard, among others

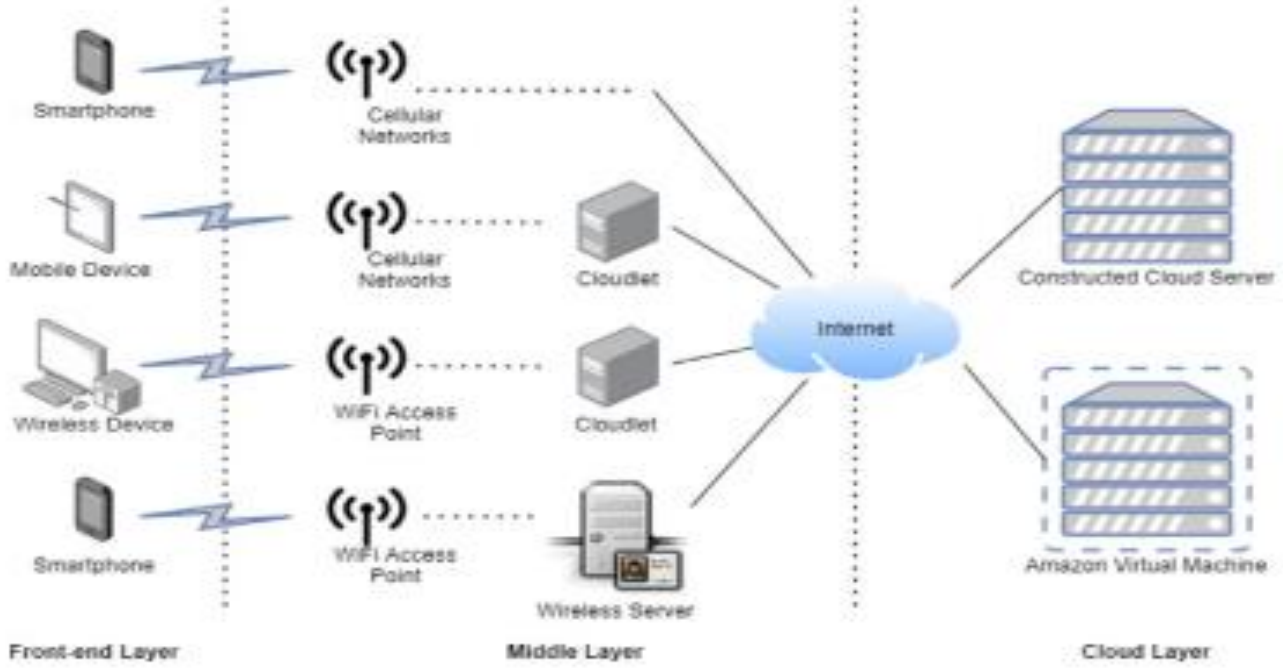
Mobile computing Architecture

- **Security**: All security mechanisms put in place to ensure a safe mobile environment; these security parameters include firewalls, biometric systems, backups and data recovery systems, intrusion detection systems, encryption, authentication, access control, and secure communication protocols to protect sensitive data and ensure the integrity and confidentiality of mobile applications and services.

Mobile computing Architecture

- **User Interface:** Mobile devices have user interfaces that are friendly and provide easy navigation with features like screens, buttons, menus, and gestures.
- **Sensors and Location Services**: Almost all Mobile devices today have different sensors (e.g., accelerometer, gyroscope, GPS) that enable them to capture data about the physical environment and user interactions. Location-based services use GPS and other positioning technologies to provide location-aware functionality in mobile applications.

Mobile cloud computing



- (Das, 2023)

Mobile cloud computing

- Mobile Cloud Computing (MCC) is a technology designed to provide a new framework in which services to mobile subscribers utilizing cloud computing.
- Due to cloud computing Cell phone users don’t have to worry effective setup i.e., CPU speed and memory limit since all the confounded calculations will be handled in the cloud.

Mobile cloud computing

- Mobile cloud computing refers to an infrastructure where both the data storage and data processing happen outside of the mobile device. Mobile cloud applications move the computing power and data storage away from mobile phones and into the cloud, bringing applications and MC to not just smart phone users but a much broader range of mobile subscribers’

Mobile cloud computing

- Mobile cloud computing makes use of cloud computing to provide services or required applications to mobile devices. This mobile application can be implemented far away using space, mobility and development software. MCC Overcomes computing, energy, and storage capacity Restriction on smart mobile devices.

Mobile cloud computing

- Mobile devices are limited in terms of computational resources, storage, and energy engineered, these motivated the introduction of Mobile Cloud Computing.
- At the network's edge, MCC frequently deploys small, lightweight cloud servers known as "cloudlets." Three-tier hierarchical application deployment architecture for rich mobile apps is developed using cloudlets in conjunction with mobile devices, and cloud data centers

Mobile cloud computing

- Mobile Cloud Computing combines all of the benefits of cloud computing, mobile internet, and mobile computing.
- Mobile cloud computing allows the use of resources based on a request; these include network, server, mobile application, storage, and computing resources in the mobile environment.

Qualities of Mobile Cloud Computing

a) Multi tenancy: The application is used to share the hardware resources, users can influence utilization of single application and database in an occurrence.

b) Scalability: Service providers can easily expand or add a service which offers scalability to the mobile users.

c) Availability: cloud services are available to the users all the time even when they are moving from place to place.

Qualities of Mobile Cloud Computing

d) Reliability: Since data is stored in the cloud the likelihood of losing it is minimized.

e) Dynamic provisioning: The resources can be added on demand dynamically instead of advance reservation.

f) Ease of integration: With the help of cloud computing technology, many services from various specialist organizations can be coordinated to meet the versatile client's requests.

Challenges in mobile cloud computing

- A. Mobile Communication Issues:
- a) Low bandwidth: The available bandwidth is usually distributed among various mobile devices, it way much slower than wired networks
- b) Service Availability: breakdown in network connectivity implies that the clients will not be able to access cloud services.

Challenges in mobile cloud computing

c) Heterogeneity: It might be difficult to satisfy MCC requirements by handling wireless connectivity with heterogeneous networks.

d) Security Issues: Security is the major concern for both mobile users and data present in the cloud. Cell phones can be exposed to various security dangers, they coordinate with global positioning system (GPS) gadget, and this can cause protection issues for subscribers.

e) Privacy Issues: Mobile data is more susceptible to unauthorized users.

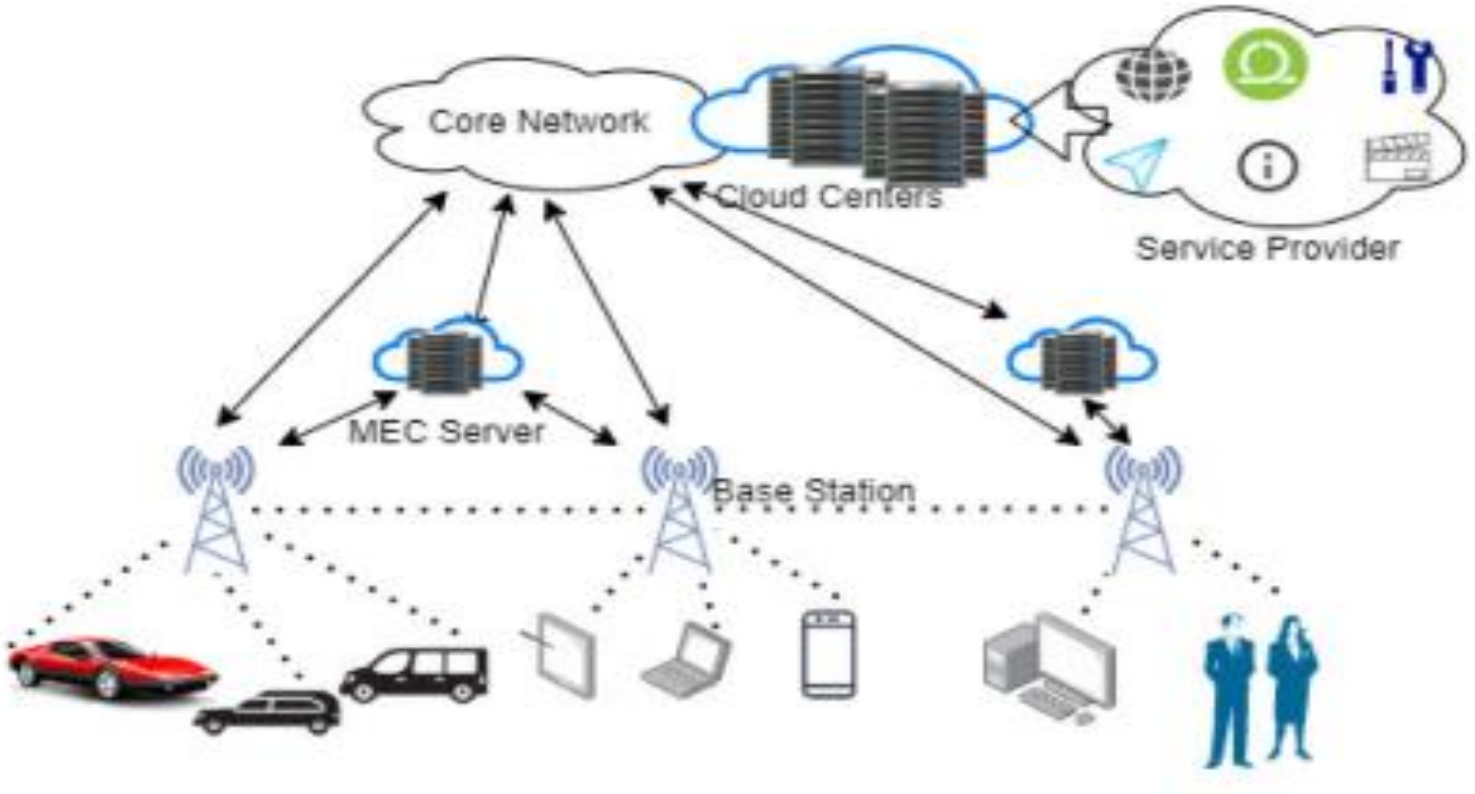
Applications of mobile cloud computing:

- Mobile Commerce: Mobile devices using this application provide various business models for commerce. Examples include mobile shopping, mobile advertising.
- Mobile Healthcare: On demand services can be provided by hospitals and healthcare organizations on the clouds by using Mobile healthcare.

Applications of mobile cloud computing:

- Mobile Gaming: This economically benefits service providers to receive potential marketing revenues.
- Mobile Learning: This concatenates e-learning and mobility. Limitations with traditional m-learning includes low transmission rate, low cost of device and constrained instructive assets. Cloud based m-learning can comprehend these constraints.

Mobile Edge Computing



- (Das, 2023)

Mobile Edge Computing

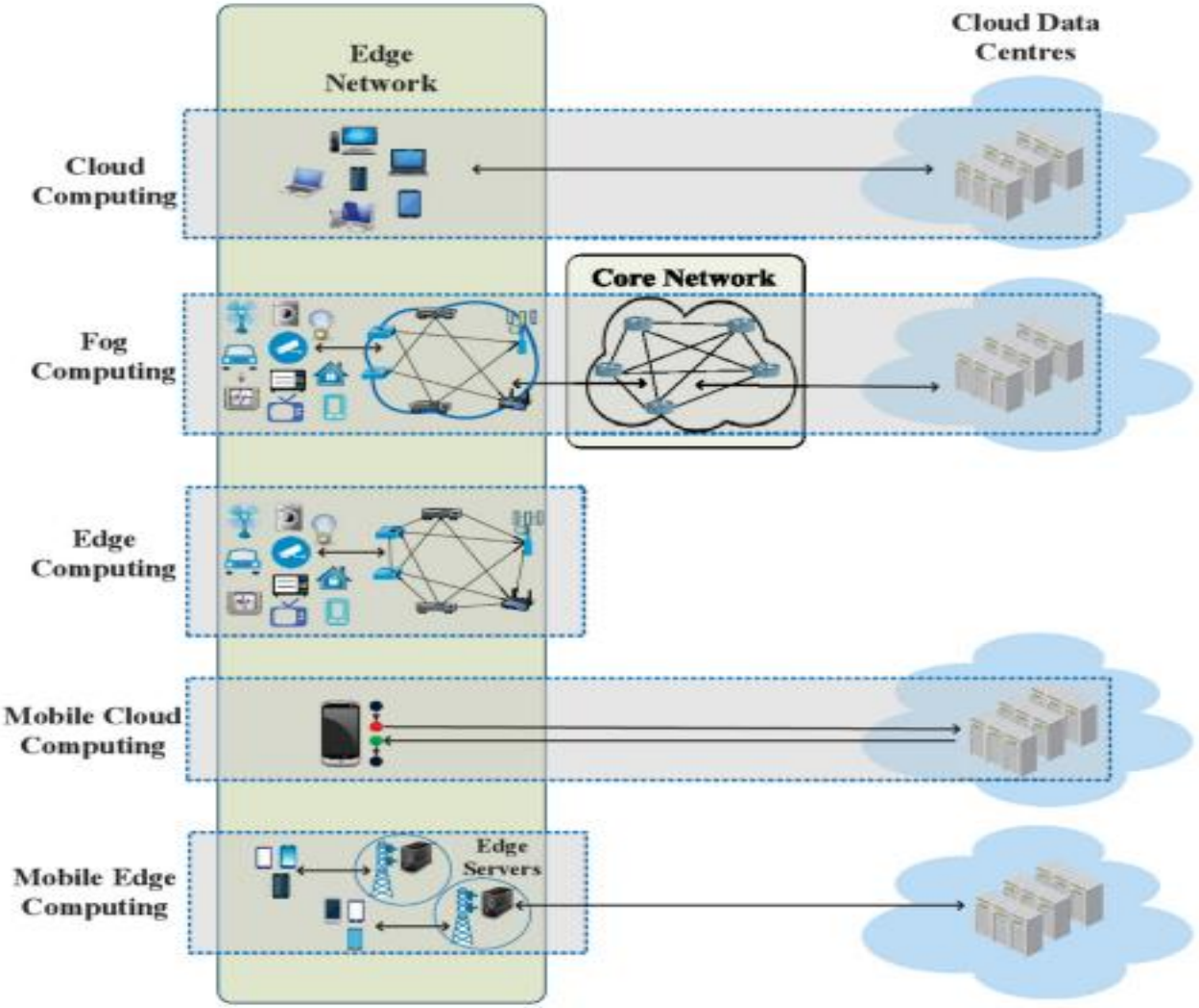
- In MCC architecture, the cloud servers are placed far away from the edge (end) devices, hence limiting performance in a network environment with high computational requirements
- Mobile-Edge Computing (MEC) is a technology introduced to allow mobile users access to the cloud and other information technology services within close range of the Radio Access Network (RAN).

Mobile Edge Computing

- The main role of Mobile- Edge Computing is to minimize latency by transferring storage and computational capacity from the core network to the edge network. Mobile Edge Computing is a model for enabling a business-oriented cloud computing platform within the radio access network at the proximity of mobile subscribers to serve delay-sensitive, context-aware applications

Mobile Edge Computing

- (Das, 2023



State of mobile applications

- **Offline Applications**
- A Bigger percentage of mobile applications are offline applications
- They act as fat client that processes the presentation and business logic layer locally on mobile devices with data downloaded from backend systems. There is periodical synchronization between the client and backend system. A fat client is a networked application with most resources available locally, rather than distributed over a network as is the case with a thin client. Offline applications, also often called native applications, offer:

Offline Applications

- Good integration with device functionality and access to its features
- Performance optimized for specific hardware and multitasking
- Always available capabilities, even without network connectivity

Disadvantages:

- No portability to other platforms
- Complex code
- increased time to market a requirement for developers to learn new programming languages

Online Applications

- An online application assumes that the connection between mobile devices and backend systems is available most of the time. Smartphones are popular due to the power and utility of their applications, but there are problems such as cross-platform issues. Here Web technologies can overcome them; applications based on Web technology are a powerful alternative to native applications.

Online Applications

- Mobiles have the potential to overcome some of the disadvantages of offline applications because they are:

• Multi-platform

• Directly accessible from anywhere

• Knowledge of Web technologies is widespread among developers, greatly minimizing the learning curve required to start creating mobile applications

Application models for mobile cloud computing

- Augmented Execution
- Augmented execution refers to a technique used to overcome the limitations of smartphones in terms of computation, memory and battery by off -loading tasks in the cloud where a cloned system image of the device is running. This process of off-loading intensive computations employs loosely synchronized virtualized or emulated replicas of the mobile device in the cloud.

Augmented Execution

- It provides an illusions that the mobile user has a more powerful, feature-rich device than actually in reality, and that the application developer is programming such powerful device without having to manually partition the application or provision proxies. Instantiating device's replica in the cloud is determined based on the cost policies which try to optimize execution time, energy consumption, monetary cost and security.

Elastic Partitioned/Modularized Applications

- Running applications in heterogeneous changing environments like mobile clouds requires dynamic partitioning of applications and remote execution of some components. Applications can improve their performance by delegating part of the application to remote execution on a resource-rich cloud infrastructure

Elastic Partitioned/Modularized Applications

- Elasticity in software can be observed as the ability to acquire and release resources on demand. Modules are units of encapsulation and units of deployment that compose the distributed application. The underlying runtime module management platform hides most of the complexity of distributed deployment, execution, and maintenance.

Application Mobility

- The mobile cloud is accessed through heterogeneous devices. In order to provide seamless user experience same applications need to run on different devices. The application mobility plays a crucial role in enabling the next generation mobile applications.

Application Mobility

- Application mobility is the act of moving application between hosts during their execution. Application mobility is closely related to process migration. Process migration is an operating system capability that allows a running process to be paused, relocated to another machine, and continued there.

Ad-hoc Mobile Clouds

- An ad-hoc computing cloud represents a group of mobile devices that serve as a cloud computing provider by exposing their computing resources to other mobile devices. This type of mobile cloud computing becomes more interesting in situations with no or weak connections to the Internet and large cloud providers. Offloading to nearby mobile devices save monetary cost, because data charging is avoided, especially favored in roaming situations.

Summary

- **Mobile computing**: Mobile computing refers the computational tasks performed by a mobile user using his smart phone. The smart phone handsets usually have very limited processing power and memory and have limited capacity to handle heavy weight computational tasks.
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Next Lecture

- Trends in Cloud Computing

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